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Seasonal Distributions of Larval Flatfishes (Pleuronectiformes) on the Continental Shelf Between Cape Cod, Massachusetts, and Cape Lookout, North Carolina, 1965-66

W. G. SMITH, J. D. SIBUNKA, and A. WELLS

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ABSTRACT

Larval flatfishes, representing 4 families, 17 genera, and 15 species, were identified from collections taken during a 1-yr survey designed to locate spawning grounds and trace dispersion of fish eggs and larvae on the continental shelf. Most flatfishes began spawning in the spring, a time of marked seasonal temperature change. The seasonal distribution of larvae indicated that: 1) bothids had longer spawning seasons than pleuronectids; 2) pleuronectids spawned largely in the northern half of the survey area during the spring; 3) most bothids spawned in the southern half, beginning in spring and continuing through early fall; 4) although cynoglossids spawned incidentally off North Carolina, most of their larvae were transported into the survey area from spawning grounds south of Cape Lookout; 5) the few representatives of the family Soleidae originated south of Cape Lookout; 6) spawning that began in the spring proceeded from south to north as the season progressed, but spawning that began in the fall proceeded from north to south, suggesting that the onset of spawning is triggered by spring warming and fall cooling; 7) most species spawned within a relatively narrow range of temperature; 8) salinity had no apparent influence on spawning.

INTRODUCTION

ruitment is a major factor determining the size of y exploited fish populations such as those found along stern seaboard. Unfortunately, we lack the needed fic information about the life histories of most coastal to relate numbers of adults to numbers of young and, n, relate numbers of young to the sequence of ical and environmental events that lead to a successful lass. The sound management policies that seem so ial during this period of increased foreign and tic fishing pressure will follow the enormously tant task of understanding life histories in their ty; not just that part dealing with adults but with all of development.

965, biologists at Sandy Hook began a 2-yr survey of fishes on the continental shelf between southern New nd and Florida. The first year we sampled from Cape Mass., to Cape Lookout, N.C.; the second year from River, N.C., to Palm Beach, Fla. We planned initially ermine spawning areas and trace the distributional s of eggs and larvae after spawning, with a view l assessing the importance of the estuarine zone as a y ground for juvenile fishes. In this paper, we discuss asonal distribution and relative abundance of flatfish , belonging to 17 genera and 15 species, collected the year of sampling along the Middle Atlantic Bight, hat portion of the continental shelf between Cape Mass., and Cape Hatteras, N.C. To assess the bution of ichthyoplankton to the Middle Atlantic Bight vaters south of Cape Hatteras, we sampled to Cape ut.

le Atlantic Coastal Fisheries Center Sandy Hook Laboratory, l Marine Fisheries Service, NOAA, Highlands, NJ 07732.

The Middle Atlantic Bight, hereafter referred to as the bight, is inhabited by an arctic-boreal group of flatfishes, largely pleuronectids, whose center of abundance lies north of Cape Cod; and a warm-temperate group, mostly bothids, that range southward to Florida and, for some species, into the Gulf of Mexico, the Caribbean Sea, and the South Atlantic Ocean (Topp and Hoff 1972). Some of the pleuronectids escape unsuitably warm inshore water in the bight by moving offshore to cool deep water in summer. Conversely, many of the bothids favor the warm inshore water in summer and some move offshore in winter, where bottom temperatures are warmer than those inshore. Despite their seasonal movements, members of both groups possess the temperature tolerance characteristic of most coastal fishes found at temperate latitudes.

METHODS

We conducted nine cruises during the survey, sampling at 92 stations situated along 14 transects (Fig. 1). The sequence of sampling varied, depending largely on existing weather conditions. With the exception of the September cruise, which was twice delayed and subsequently rescheduled after sampling the four northernmost transects, nearly all cruises were completed. Rough weather precluded our sampling along transects A and B on the first cruise in December, and at six stations on the second cruise in January (Table 1).

Sampling procedures, equipment, hydrographic data, and laboratory procedures are described by Clark et al. (1969). Two Gulf V nets (Arnold 1959) were towed for 30 min in a step oblique pattern to collect plankton. Net 1 fished for 5 min each at six 3-m depth intervals from the surface to 15 m; the other, net 2, at six intervals from 18 to 33 m. At depths less than 33 m, we decreased the number of towing depth

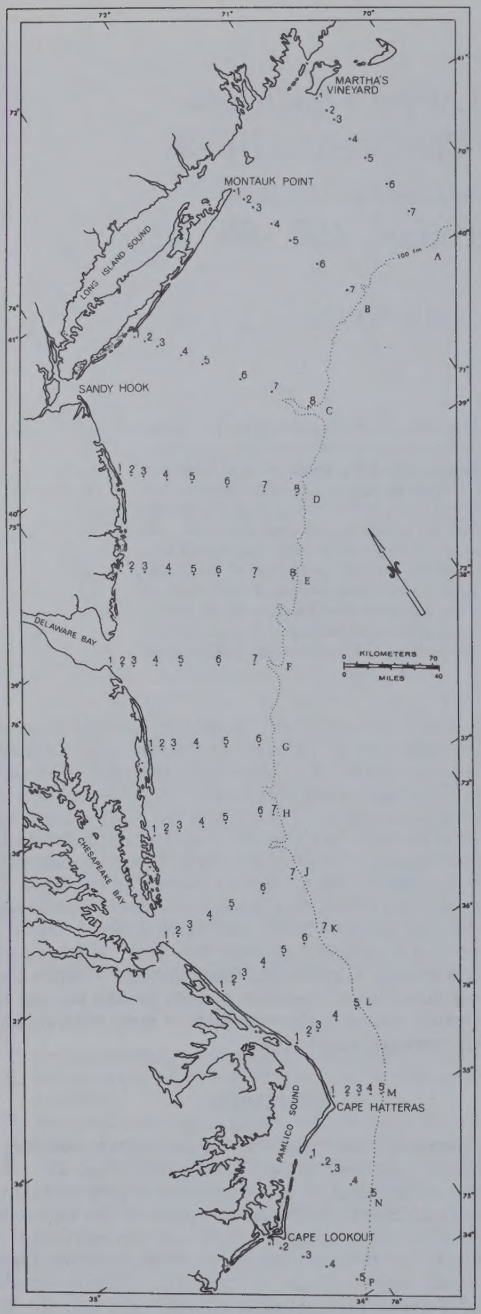


Figure 1.—Transects (lettered) and collecting stations (numbered) of 1965-66 plankton survey between Cape Cod and Cape Lookout.

intervals and increased the towing time at each interval for net 2. The tow profile for net 1 was similarly adjusted in depths less than 15 m (Smith 1973).

Because of variations in the towing time at 3-m c intervals between inshore and offshore stations, it w necessary to standardize tows to obtain measures of relati abundance. A standard tow consisted of one or both fishing for 5 min at each of the six depth intervals with vertical sampling range. We adjusted the catches equalize sampling effort at all depth intervals when eit net was limited to sampling at less than six intervals. example, when a net fished at only three intervals d the 30-min tow, the catch was halved. When two inte were fished, it was reduced by two-thirds. We combined adjusted catches of nets 1 and 2 at stations where both fished simultaneously. All catches discussed are adju

If more than 100 larvae of a species were caught a station, we usually measured a subsample of 25 random selected specimens to the nearest 0.1 mm and adjusted number measured to coincide with the total catch, whic recorded in size increments of 1.0 mm.

In spite of the possibility of year-to-year variations in t onset, duration, and success of spawning, data colle during the two calendar years of the survey were comb and treated as a single complete spawning season for species. For example, we discuss results of fall and win spawning by beginning with the October and Novem 1966 catches, and continue with results of December January 1966, etc. We determined monthly shift spawning grounds and the duration of spawning by plotti the distribution of larvae by size categories, provided lar occurred in sufficient numbers to merit such anal Figures showing the distribution of larvae by cruise in damaged larvae that could not be measured, but tables a of course, those figures depicting the distribution of lar by size categories do not. Thus, the number of larvae i tables and the figures showing the distribution of larva size do not always correspond with the figures showing distribution of all larvae collected on a cruise. If we cau only a few larvae of a species, a figure showing their d bution for that cruise may not be included. These larvae however, included in the composite figure, or that fig showing the combined catch for all cruises on which caught larvae of a particular species. Thus, the comp figure for a species may show larval occurrences tha not evident on other figures.

Because larvae hatch and metamorphose at sizes that intraspecifically similar but interspecifically different, size categories vary between species. We assumed tha spawning grounds for each species were represented by area encompassing stations where we caught small larv The spawning season included months when small la occurred in our samples.

ENVIRONMENTAL INFLUENCES ON THE DISTRIBUTION OF FISHES

Both water temperature and salinity undergo pronou seasonal changes within the bight, due mostly to chang weather and runoff from the numerous adjacent estua Water temperatures increase rapidly during the spri Warming begins inshore along the southern end of the b and progresses northward and seaward as cold winter w give way to warm spring and summer breezes (Norcross Harrison 1967). A seasonal thermocline develops throu out most of the bight by summer, and the water co remains thermally stratified until fall. A unique cell of

Table 1.--Cruise schedule and sequence of sampling transects during R. V. Dolphin ichthyoplankton survey, 1965-66. Sampling interruptions in excess of 48 hr are shown, whether or not the sampling sequence was affected.

Cruise	Sampling dates	Transect or station sampling sequence	No. of stations
D-65-4	Dec. 3-15, 1965	C to P	80
D-66-1	Jan. 25-26, 1966	B, A-1 and -2	86
	Feb. 2-9, 1966	C to P	
D-66-3	Apr. 6-9, 1966	A to D	92
	Apr. 13-16, 1966	E-1 and -2, F to J-7 to -3	
	Apr. 19-21, 1966	J-1 and -2 to P	
	Apr. 22, 1966	E-8 to -3	
D-66-5	May 12-25, 1966	A to P	92
D-66-7	June 17-20, 1966	A to D	92
	June 22-25, 1966	L to P	
	June 25-29, 1966	K to E	
D-66-10	Aug. 5-10, 1966	A to F	92
	Aug. 21-26, 1966	G to P	
D-66-11	Sept. 13-14, 1966	A and B (except B-3)	30
	Sept. 17-18, 1966	B-3, C and D	
D-66-12	Sept. 28-Oct. 6, 1966	M, N, L to F, E-1 to -3, D-1 to -3	92
	Oct. 11-15, 1966	E-4 to -8, F-8 to -4, C to A	
	Oct. 20, 1966	P	
D-66-14	Nov. 9-14, 1966	E to J (except F-7, E-8)	92
	Nov. 15-19, 1966	P to K, F-7, E-8	
	Dec. 1-4, 1966	D to A	

ter forms below the thermocline from New York to as far ıth as Virginia (Bigelow 1933; Ketchum and Corwin 1964). e cell's pronounced effect on the distribution and vements of several summer spawning fishes is reflected the patterns of their egg and larval distributions. Late nmer and fall storms usually break down the thermal atification, and water temperatures cool rapidly there- er. By winter, the water column is isothermal, except ır the outer edge of the shelf where temperatures are ıally warmer near the bottom than at the surface.

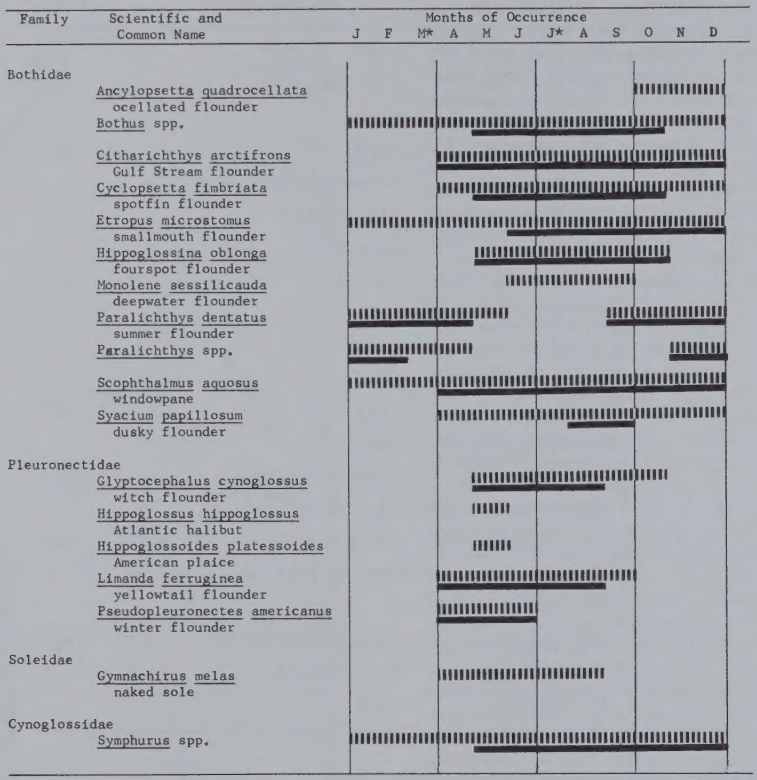
Salinity throughout the bight seldom reaches 35‰, and it usually less than 30‰ at the mouths of the major uaries. Whereas water temperatures often seem related the spawning habits of some species, we were unable to ate our salinity observations to spawning or the tribution of flatfish larvae.

Circulation within the bight has been studied largely by release and return of drift devices such as bottles and bed drifters. Nontidal drift is generally west to thwest but it changes seasonally, and surface and surface currents sometimes flow in opposite directions mpus and Lauzier 1965; Norcross and Stanley 1967). nd and runoff are the external forces most responsible for tidal water movement in the bight. The intrusion of high nity ocean water into the bight is poorly understood, but it probably occurs through exchange of shelf and slope water along the outer edge of the shelf (Bumpus 1973). Much of the coastal water turns seaward near Cape Hatteras and becomes entrained in the Gulf Stream (Norcross and Harrison 1967).

The Gulf Stream passes within 22 km of Cape Hatteras. As the stream meanders northward, it acts as a transport vehicle for larvae spawned throughout the warm-temperate and tropical waters of the western North Atlantic. Thus, it is difficult to predict the origin of larval fishes caught off the North Carolina capes. Many of the larvae we caught off North Carolina, and some caught as far north as New York, probably originated somewhere off our southeast coast and were subsequently transported northward by the stream.

The literature falls far short of providing the information needed to describe adequately how environmental factors influence spawning, and the subsequent distribution of eggs and larvae in the bight. Although our survey was not designed to permit such detailed analyses, some of the distributional patterns of larvae can be related to circulation trends; and the onset, extent, and duration of spawning often can be associated with rather narrow ranges of temperature. These associations are noted throughout the text.

Table 2.--The seasonal occurrence of flatfish larvae (IIIII) collected during 1965-66 plankton survey between Cape Cod and Cape Lookout. Solid line (▬) represents duration of spawning within the survey area, based on the occurrence of small larvae. Larvae were presumed to be present during months not sampled (*) if they were caught during preceding and subsequent months.



RESULTS AND DISCUSSION

Most of the pelagic fishes in the Middle Atlantic Bight are seasonal migrants, and many of those that spawn there do so during their spring immigration into the bight or fall emigration out. Because migrations through the bight are closely tied to water temperatures, spawning is usually localized and intense at its onset, but shifts seasonally and increases in areal extent as the migrations advance. In the spring when waters are warming, spawning generally proceeds northward and often begins south of the bight. In the fall when coastal waters are cooling, spawning proceeds southward and for some fishes begins north or east of the bight.

Although flatfishes move seasonally within the bight, they do not migrate long distances and most are considered residents of the bight. Despite the limited movements of adult flatfishes, their seasonal spawning patterns resemble those of migratory pelagic fishes such as Atlantic mackerel, *Scomber scombrus*, and Atlantic menhaden, *Brevoortia tyrannus*, by proceeding northward in the spring and southward in the fall. Thus, it seems that the onset of spawning by fishes that are migratory, as well as those tha are not, is closely tied to temperature in the bight.

The survey area does not encompass the entire range f any of the species discussed here. We assume, however that larvae represented spawning that occurred within th bight if they were collected in significant numbers on sever cruises. Although the young of several flatfishes utili estuaries as nursery grounds, those that survive will retur to the offshore waters of the bight and eventually will b recruited into the spawning stock(s). From a biologic standpoint, fishes so limited in their movements mal excellent subjects for both study and management.

The occurrence of pelagic larval stages is usually mor protracted than the actual spawning season, but we used th presence of larvae presumed to have been recently hatche to estimate the approximate duration of spawning. Ou collections of larvae indicate that the pleuronectids hav short spawning seasons characteristic of fishes found water with seasonally variable temperatures, and th bothids have extended spawning seasons characteristic warm-water fishes that are adapted to less severe seasona changes (Table 2). Some of the bothids represented in o collections apparently spawned throughout the year, bu

Table 3.--The seasonal distribution of ocellated flounder, Ancylopsetta quadrocellata, larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date: 66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	Total
	Number of larvae			
2.1-3.0	1		1	2
3.1-4.0	2	3	4	9
4.1-5.0	3	5	4	12
5.1-6.0	4	3	2	9
6.1-7.0	2	1		3
7.1-8.0		2		2
8.1-9.0	—	2	—	2
Total	12	16	11	39

the possible exception of the Gulf Stream flounder, *arichthys arctifrons*, not in the bight. All of the soleid e and most of the cynoglossid larvae in our collections nated south of the survey area.

amily Bothidae—Lefteye Flounders

ncylopsetta quadrocellata Gill, ocellated flounder.—llated flounder range from North Carolina to Florida and the Gulf of Mexico (Gutherz 1967). The larvae have not described. We based larval identifications on a combi-n of marginal fin ray and vertebral counts taken from -stage larvae collected on this survey and one that wed in 1967-68 between North Carolina and Florida. acteristic pigment patterns allowed us to identify imens that lacked the adult numbers of meristic nents.

ecause we sampled only the extreme northern end of the ated flounder's range, larvae seldom appeared in our ctions. During the three cruises between October and ember, we caught 39 larvae (Table 3), all at stations h of Cape Hatteras. Most were caught off Cape Lookout may represent spawning that occurred south of the ey area (Fig. 2).

othus spp.—Our collections contain at least two species *othus* larvae. Based on fin ray and vertebral counts from photographs of 21 specimens >12 mm, we identified *. ocellatus* (Agassiz). The remaining 15 could not be tified positively. Insufficient ossification prevented tification of specimens <12 mm beyond the generic , so all the larvae are treated as *Bothus* spp. Kyle (1913) ribed development of advanced larval stages of the s *Bothus*, but larvae of the different species have not described.

tare (1962) concluded, from gonadal studies, that *B. tus* spawned almost year-round. Her larval collections ated a major spawning peak in July and a minor peak in ember. Larvae occurred year-round in our samples, ly in that part of the survey area in or near the Gulf am off North Carolina. We noted peaks in their abundance in May and November, but, because of the unknown distributional influences of the stream, we do not know whether such peaks represent the time of actual spawning peaks.

We judge that larvae collected in February represented the "beginning" of spawning because of their small numbers and limited size range (Table 4). We caught one larva near the outer edge of the shelf between Cape Hatteras and Chesapeake Bay, the rest between the North Carolina capes. The catch in April increased slightly, both in numbers and size range, but the distribution of larvae remained limited to the outer half of the shelf between capes Lookout and Hatteras, as it was in January.

The distribution of larvae in May was unchanged from that in April, but the catch increased sharply, owing largely to a concentration of larvae between the capes (Fig. 3). If the larvae caught thus far were transported into the survey area by the Gulf Stream, the increased number of small larvae caught in May suggests that spawning had moved northward since the previous cruise in April (Table 4). There was little change in either the distribution of larvae or the center of larval abundance from May to June (Fig. 4).

The catch dropped sharply by August (Table 4). The areal extent of larval distribution remained much the same as before, except that the young fish were closer to shore than on previous cruises. An 11-mm larva caught at the most seaward station off southern New England represented the northernmost occurrence of the survey (Fig. 5).

The catch increased in October, perhaps reflecting peak spawning by one of the species represented in our collections (Table 4). The pattern of distribution changed somewhat from that of earlier cruises by extending northward along the outer banks to Virginia. The center of abundance, however, remained along the edge of the shelf between capes Hatteras and Lookout (Fig. 6).

We caught more larvae in November than in any other month (Table 4). The distribution of larvae was similar to results of cruises before September, when the young fish were confined to that part of the survey area south of Cape Hatteras. The major concentration occurred near the edge of the shelf (Fig 7).

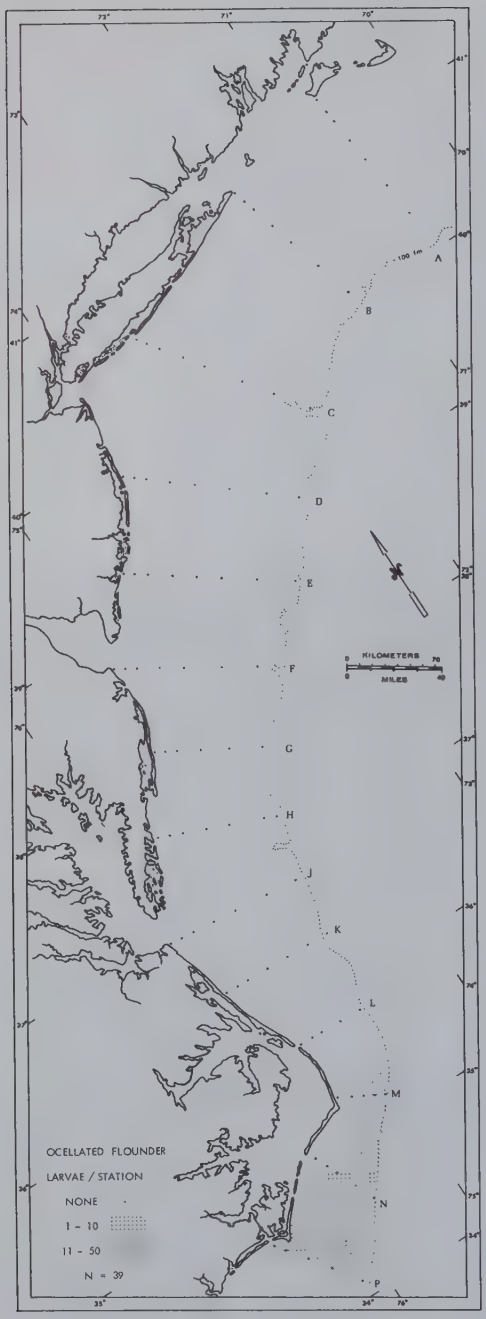


Figure 2.—Distribution and relative abundance of ocellated flounder, *Ancylopsetta quadrocellata*, larvae collected during 1965-66 survey.

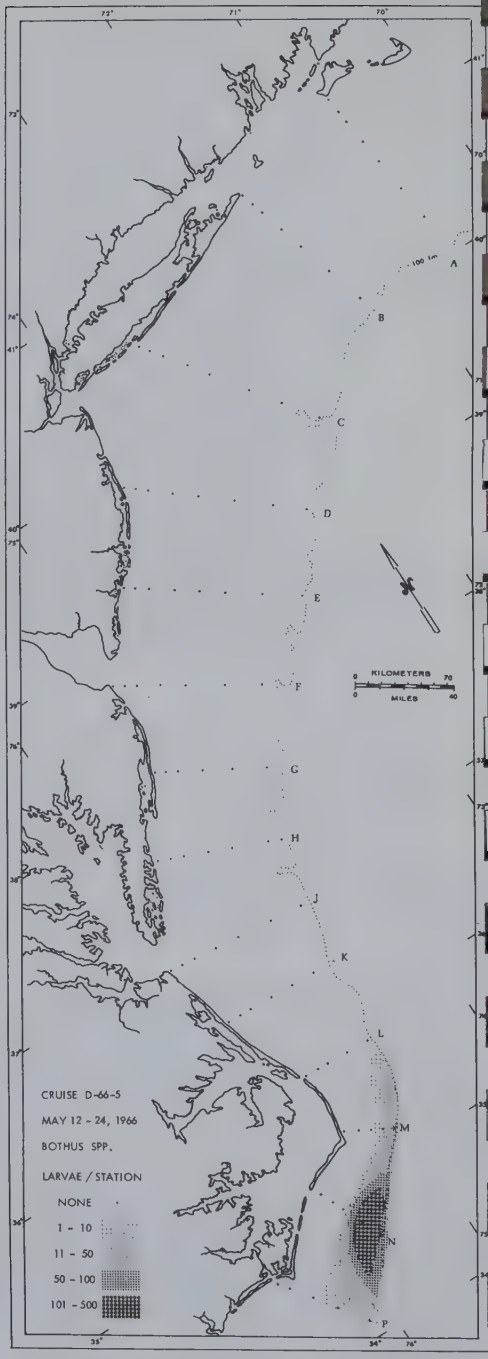
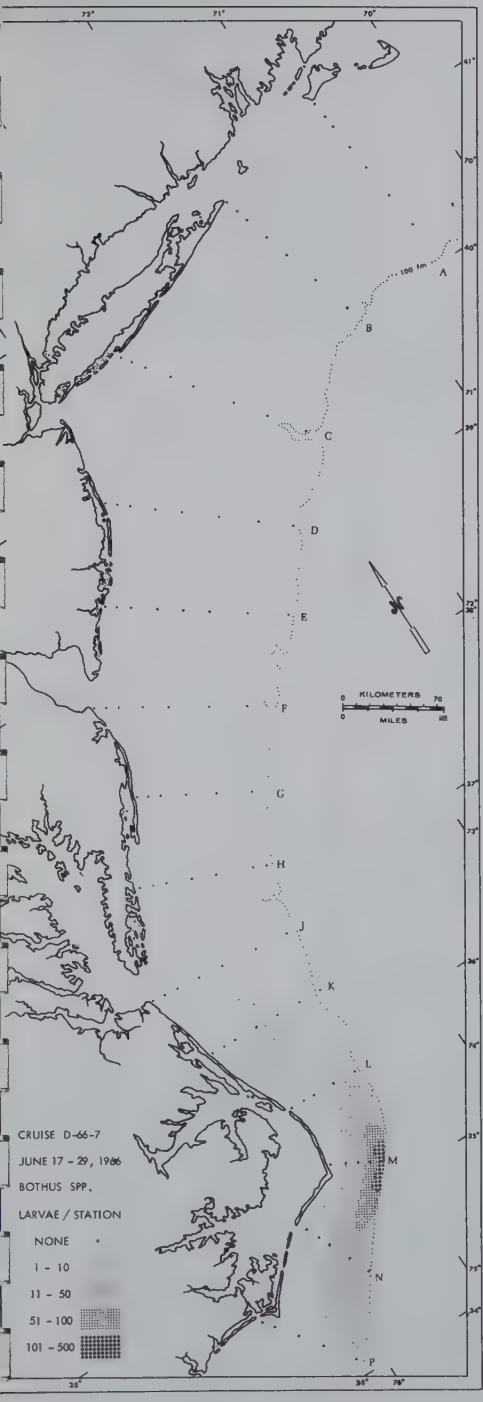


Figure 3.—May 1966. Distribution and relative abundance o
Bothus spp. larvae.



ure 4.—June 1966. Distribution and relative abundance of *Bothus* spp. larvae.

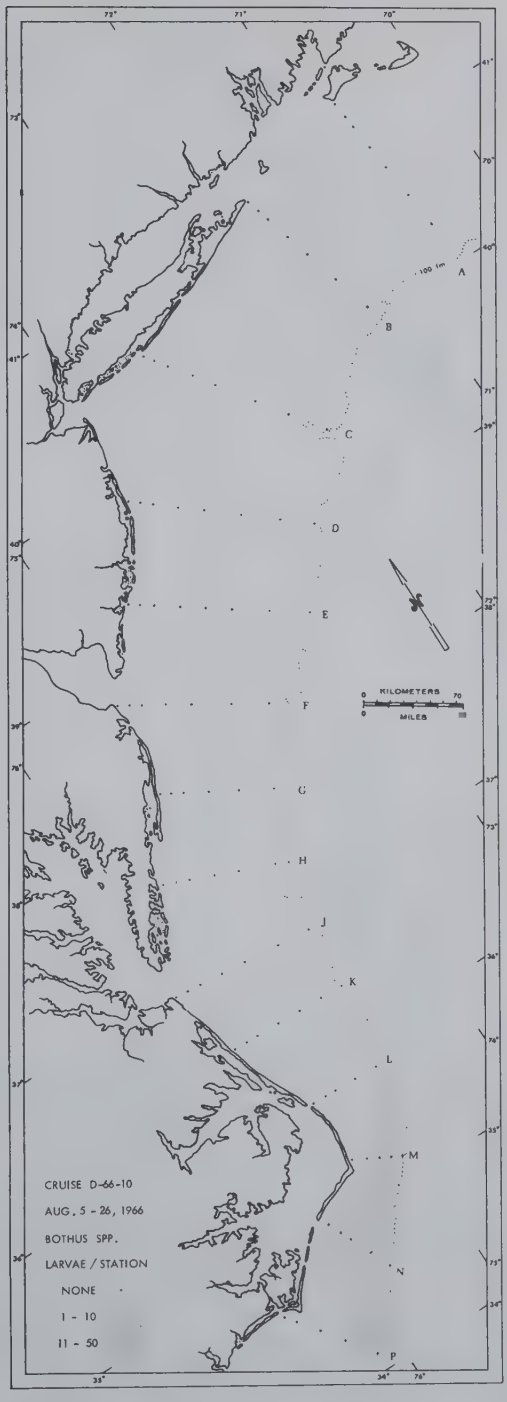


Figure 5.—August 1966. Distribution and relative abundance of *Bothus* spp. larvae.

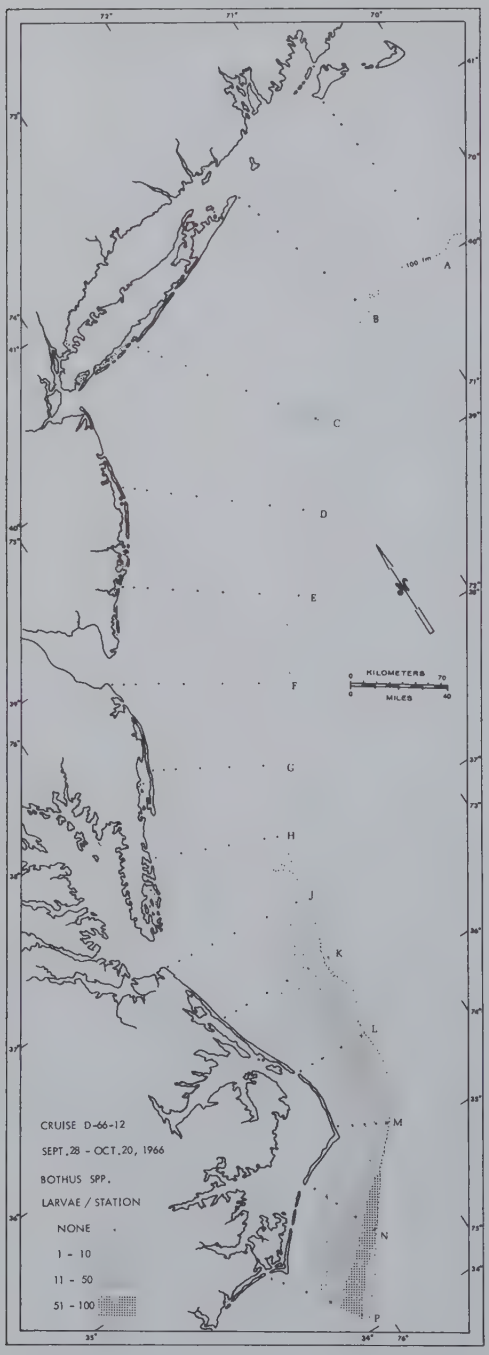


Figure 6.—September to October 1966. Distribution and relative abundance of *Bothus* spp. larvae.

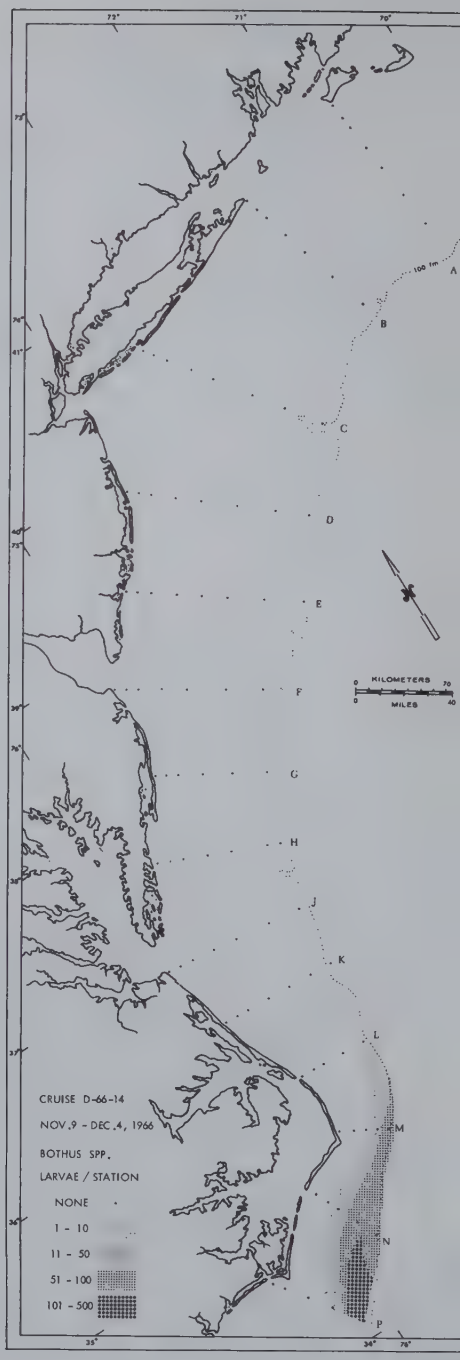


Figure 7.—November to December 1966. Distribution relative abundance of *Bothus* spp. larvae.

Table 4.--The seasonal distribution of Bothus spp. larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date: 66-1 Jan.-Feb.	66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	Total
	Number of larvae									
2.1- 3.0		3	31	9	4		16	12	10	85
3.1- 4.0	1	12	78	40	9		34	55	28	257
4.1- 5.0	2	5	122	81	17		58	119	30	434
5.1- 6.0	1	3	66	48	8		57	65	27	275
6.1- 7.0	1	4	29	33	1		34	39	6	147
7.1- 8.0	4	2	9	27	3		23	18	5	91
8.1- 9.0	1	1	4	7	3		16	9	2	43
9.1-10.0			2	6	4		6	19	4	41
10.1-11.0		1	2	4	1		2	9		19
11.1-12.0		2	1	1	2		4		2	12
12.1-13.0					1		3	3		7
13.1-14.0			1	2				1	1	5
14.1-15.0			1				4			5
15.1-16.0		1				1				2
16.1-17.0					1					1
17.1-18.0				1	1				2	4
18.1-19.0									1	1
19.1-20.0		1							1	2
20.1-21.0										
21.1-22.0								1		1
Total	10	35	346	259	55	1	257	350	119	1,432

catch declined in December. The distribution of was restricted to the southern end of the survey area, t for five larvae (7.9 to 10.6 mm) that we caught near lge of the shelf off New Jersey (Fig. 8).

oughout the survey, the center of larval abundance red along the outer edge of the shelf between capes ras and Lookout (Fig. 9). This consistency in the bution of *Bothus* larvae led us to believe that most transported into the survey area by the Gulf Stream. se the duration of the pelagic larval life varies ding to external conditions (Kyle 1913), we cannot late as to where or when the larvae originated. Colton attributed the occurrence of *B. ocellatus* larvae on es Bank to an influx of Gulf Stream water. This is a l explanation for the occurrence of larvae in the ern part of our survey area.

harichthys arctifrons Goode, Gulf Stream flounder.—Stream flounder are common in the bight, where they deeper water and range farther north than mouth flounder, *Etropus microstomus*, which they y resemble. They occur most frequently in depths >40 m, whereas smallmouth flounder generally inhabit depths <40 m (Gutherz 1967; Richardson and Joseph 1973). The reported range of Gulf Stream flounder extends from Georges Bank to Charleston, S.C. (Bigelow and Schroeder 1953), and southward along both coasts of Florida, and Yucatan, Mexico (Gutherz 1967). The larvae were described by Richardson and Joseph (1973).

The occurrence of larvae in collections from all but the late January-early February cruise suggested that Gulf Stream flounder have a prolonged spawning season in the bight. Although they might spawn year-round, our collections indicate that spawning began in late spring, peaked during the summer, and declined sharply by fall.

In June, we caught 13 larvae at three stations: two off Virginia and one off North Carolina. All were caught nearshore over depths shallower than those where adults usually occur. With two exceptions, the larvae were <3.1 mm and presumed to represent the onset of the 1966 spawning season in the bight (Table 5).

Spawning evidently reached its peak in July, since we caught the greatest number of larvae in August when their distribution was continuous from southern New England to

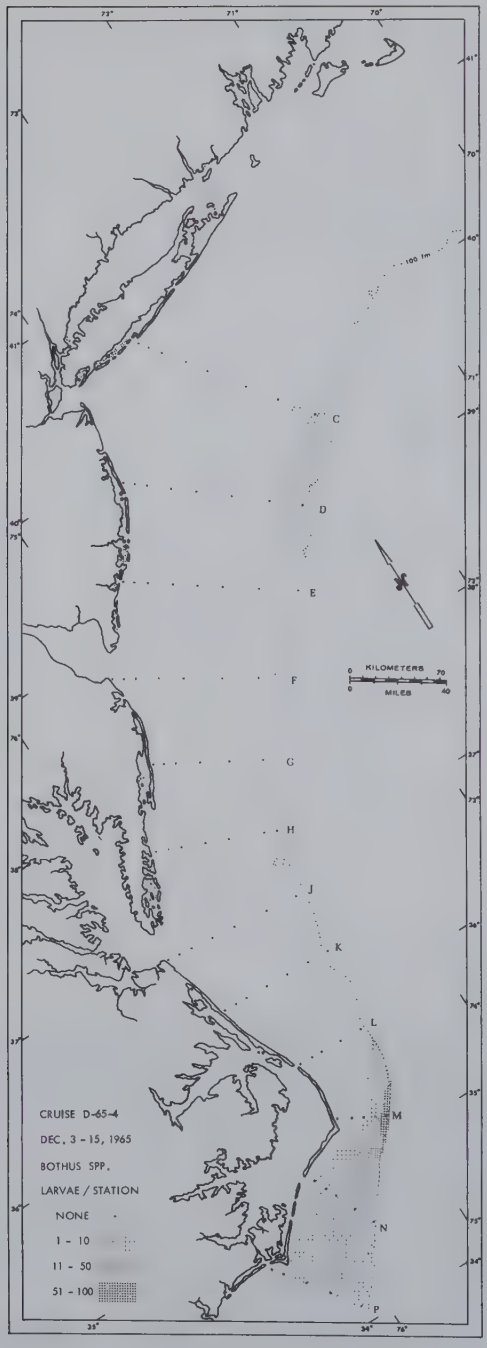


Figure 8.—December 1965. Distribution and relative abundance of *Bothus* spp. larvae.

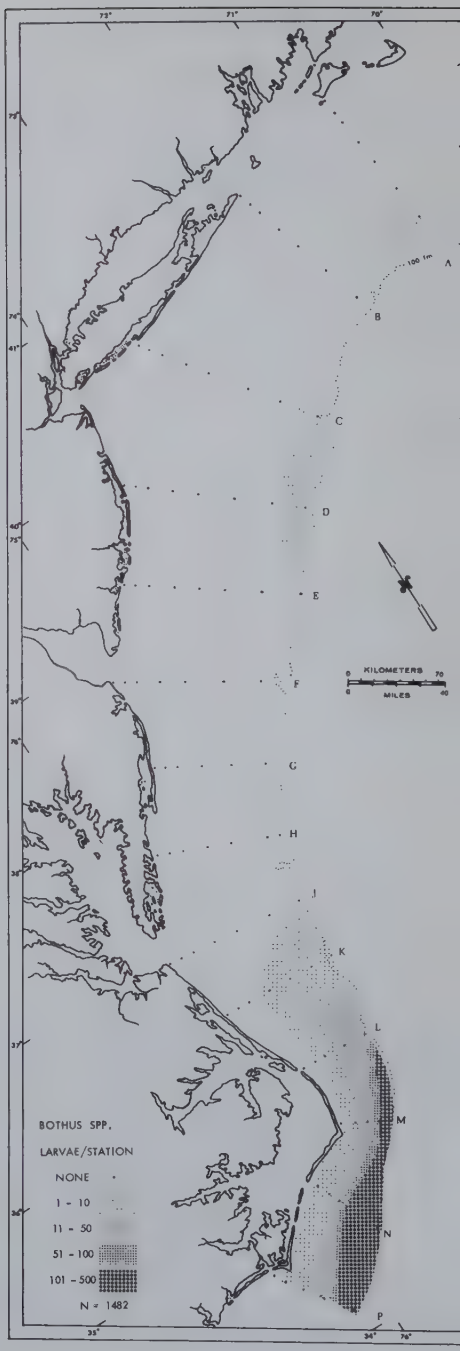


Figure 9.—Distribution and relative abundance of *Bothus* s larvae collected during 1965-66 survey.

Table 5.--The seasonal distribution of Gulf Stream flounder, Citharichthys arctifrons, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae < 4.1 mm represented recent spawning.

Larval length (mm)	Cruise and date								
	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	66-3 Apr.	66-5 May	Total
	Number of larvae								
1.1- 2.0	2	19							21
2.1- 3.0	9	169	13	13			1		205
3.1- 4.0		481	324	236	3	1	4	1	1,050
4.1- 5.0		629	693	518	10		6		1,856
5.1- 6.0		1,034	630	527	22	3	4		2,220
6.1- 7.0		946	487	1,018	71	7	3		2,532
7.1- 8.0		375	216	452	41	7	4		1,095
8.1- 9.0	1	234	144	260	31	9	1	2	682
9.1-10.0	1	77	112	275	24	3			492
10.1-11.0		44	74	116	12	2		1	249
11.1-12.0		63	28	68	13	2	3		177
12.1-13.0		36	36	37	7		1		117
13.1-14.0		25	30	39	3		1		98
14.1-15.0		19	38	30	6				93
15.1-16.0		2	1	13	2				18
16.1-17.0				1	2				3
17.1-18.0				2					2
Total	13	4,153	2,826	3,605	247	34	28	4	10,910

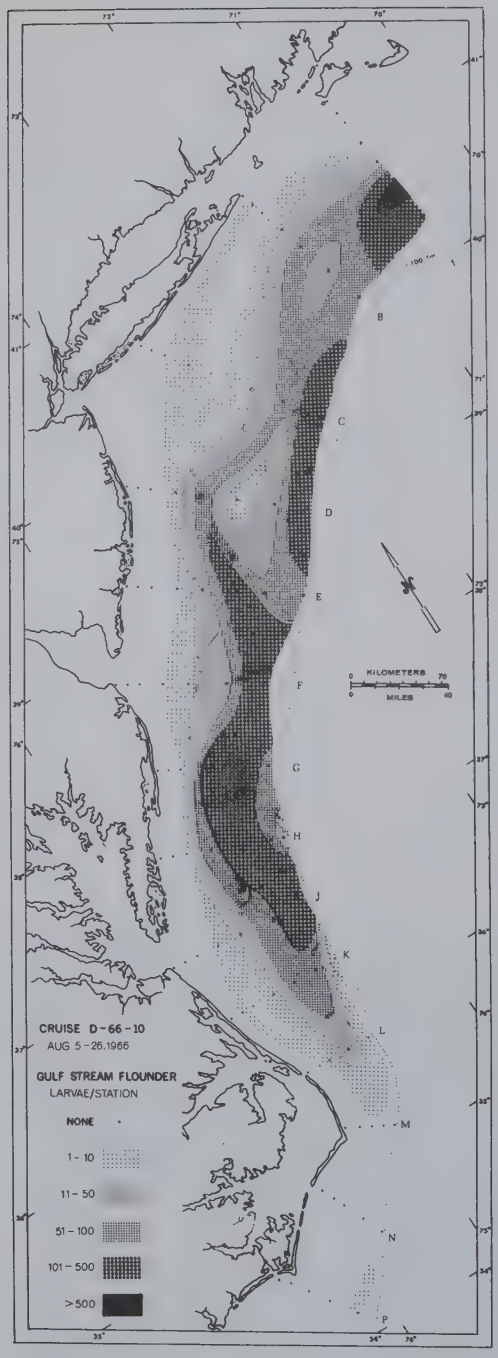
e Hatteras. Although we caught larvae over depths as al as 20 m, the center of abundance extended along the er half of the shelf between southern New England and sapeake Bay over depths of 30 to 175 m. Based on the ribution of larvae <4 mm, the most recent spawning was ered off New Jersey, but the distribution of larvae 4 to 8 indicated that heavy spawning had taken place as far th and east as Cape Cod in July (Fig. 10). Although the ribution of larvae overlapped the boundaries of the cold om water off Long Island and New Jersey, the major centrations of recently spawned larvae, those <4 mm, e generally outside the periphery of the coldest water. letheless, if concentrations of small larvae are indicative learby spawning, the Gulf Stream flounder spawns in der water than any other member of the family that wns in the bight. Despite this flounder's tolerance of cold er, our data indicate that spawning began in the hern part of the bight and progressed northward, a nd that we associate with spring warming.

During the abbreviated September cruise, larvae were ght throughout the area sampled. They were abundant r a wide part of the shelf, but the major concentration urred south of Long Island over bottom temperatures ween 6° and 8°C (Fig. 11). Larvae were more abundant he part of the survey area which we sampled in tember than in August, but, based on the relative numbers of small larvae taken along the same transects on the two cruises, we concluded that spawning had peaked in July or, at the latest, early August (Table 5).

We caught larvae in October from southern New England to Oregon Inlet, N.C. The center of abundance extended along the seaward half of the shelf between Long Island and Chesapeake Bay over depths of 35 to 120 m and bottom temperatures between 7° and 11°C (Fig. 12). Although a small patch of larvae <4 mm was situated east of Delaware Bay, the overall distribution by size indicated that the height of the spawning season had passed (Table 5).

The catch dropped off sharply in November, and no concentrations were evident. The near absence of larvae <4 mm substantiated the sharp decline in spawning noted in October (Table 5). The distribution of larvae receded to Long Island at the northern end of the survey area and in outline closely resembled that of the area of major abundance found on the previous cruise (Fig. 13). This suggests that circulation had little effect on the transport of larvae. The catch declined further in December (Fig. 14). None occurred in late January or early February.

Although larvae were absent from our January collections, we caught intermediate-sized specimens off Long Island and southern New England, and both large and small specimens off North Carolina, in April and May (Table 5). Despite the absence of larvae from our winter collections,



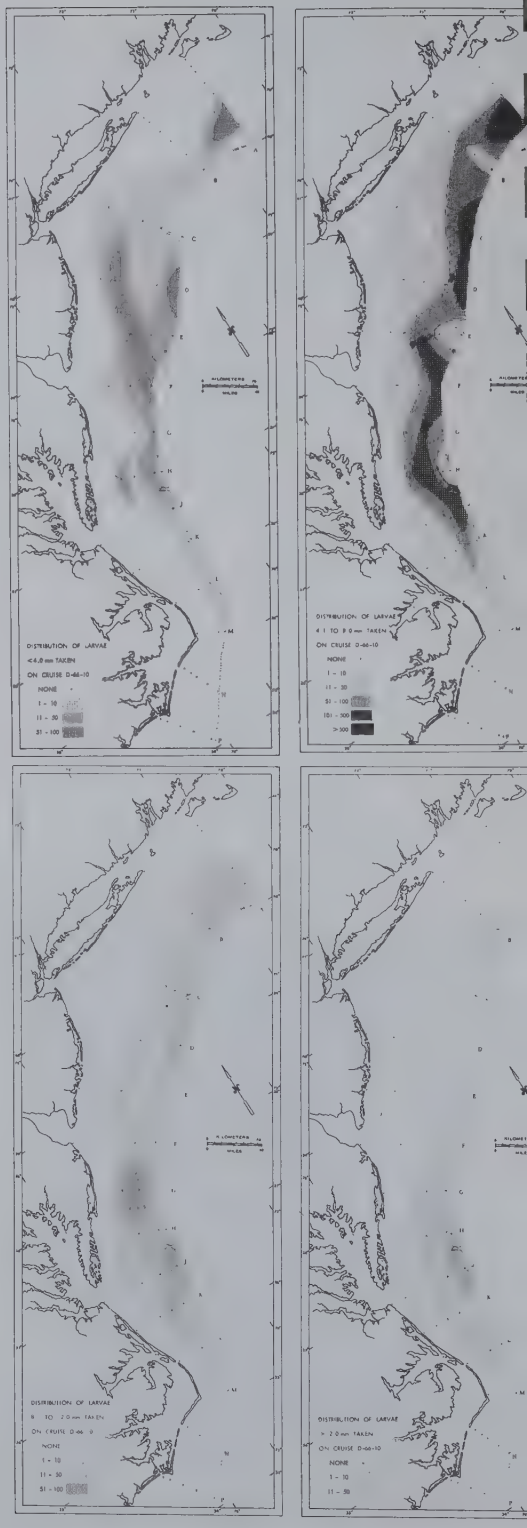


Figure 10.—August 1966. Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm, > 12.0 mm.

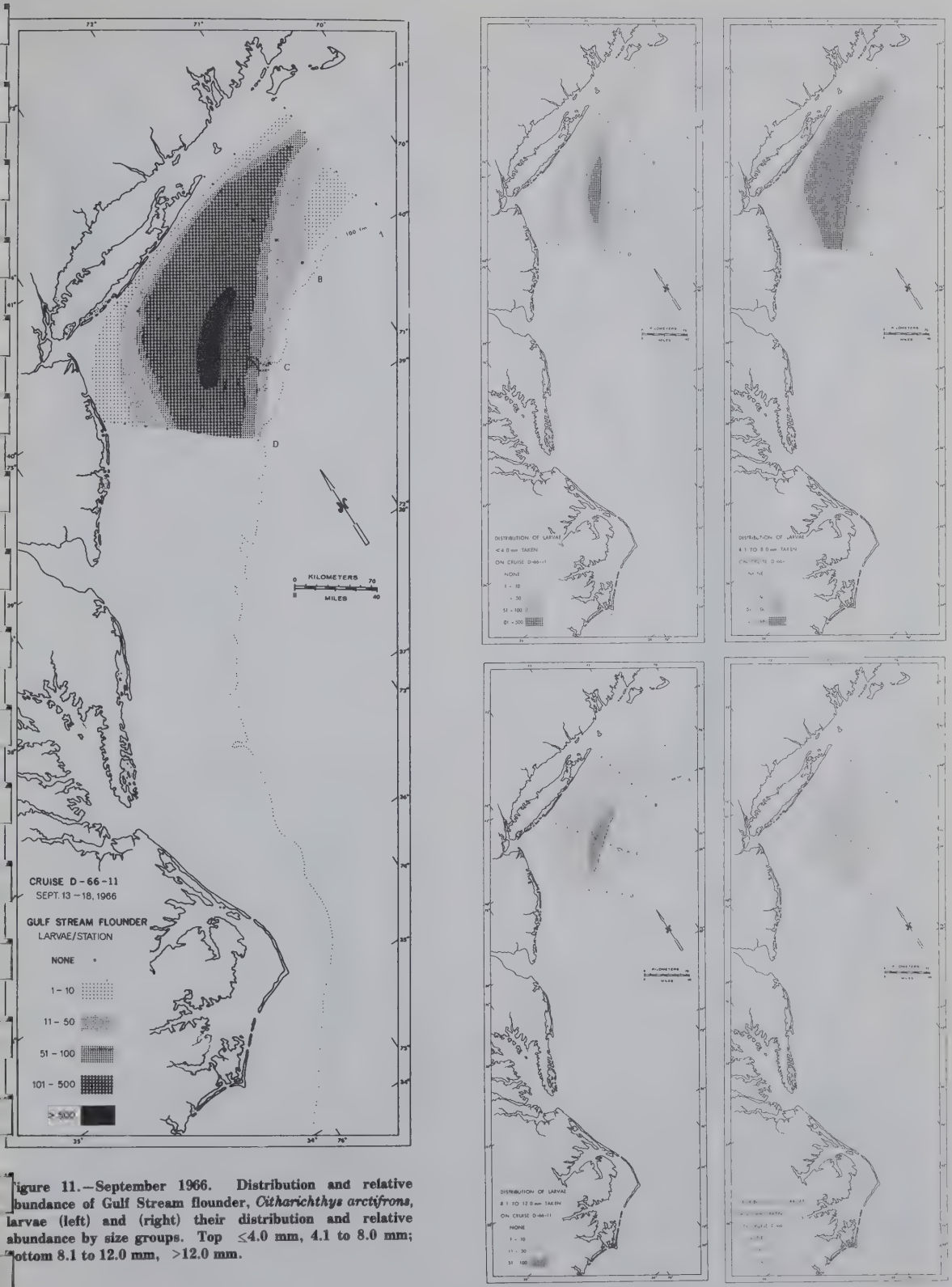
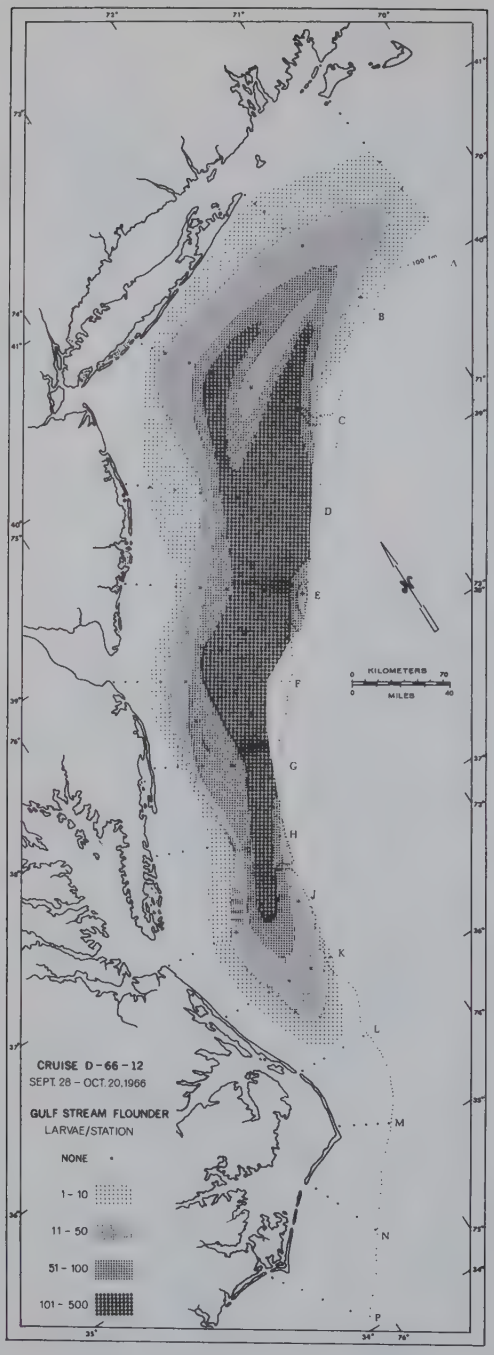


Figure 11.—September 1966. Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm, >12.0 mm.



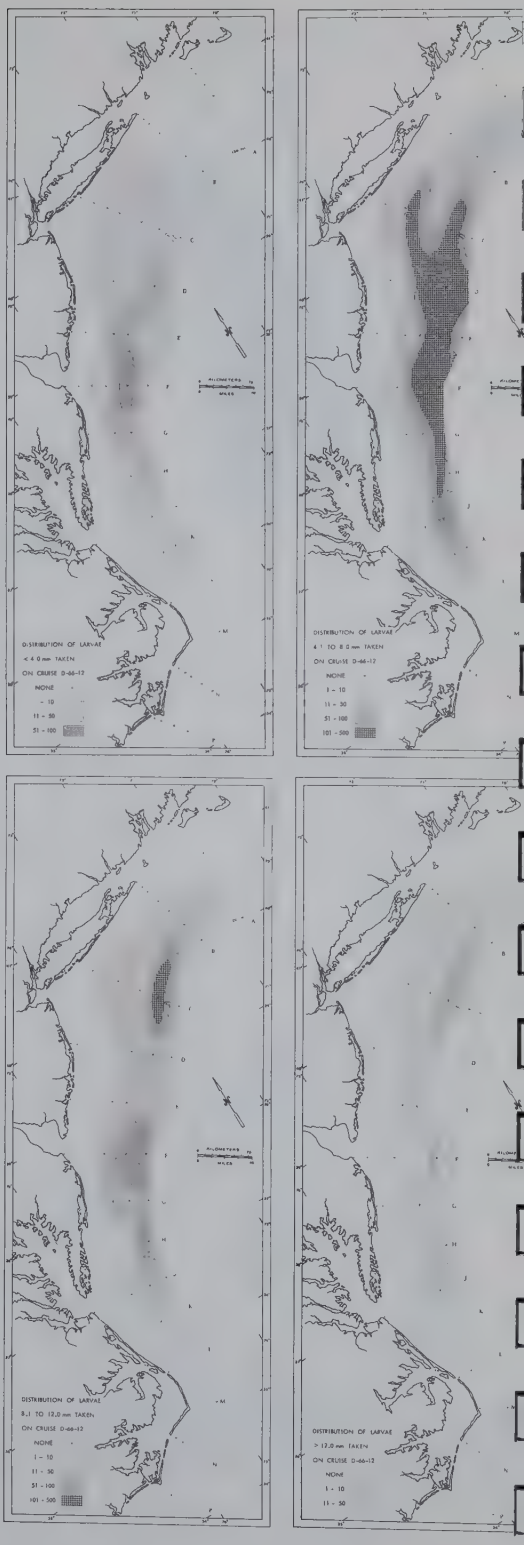


Figure 12.—September to October 1966. Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm, >12.0 mm.

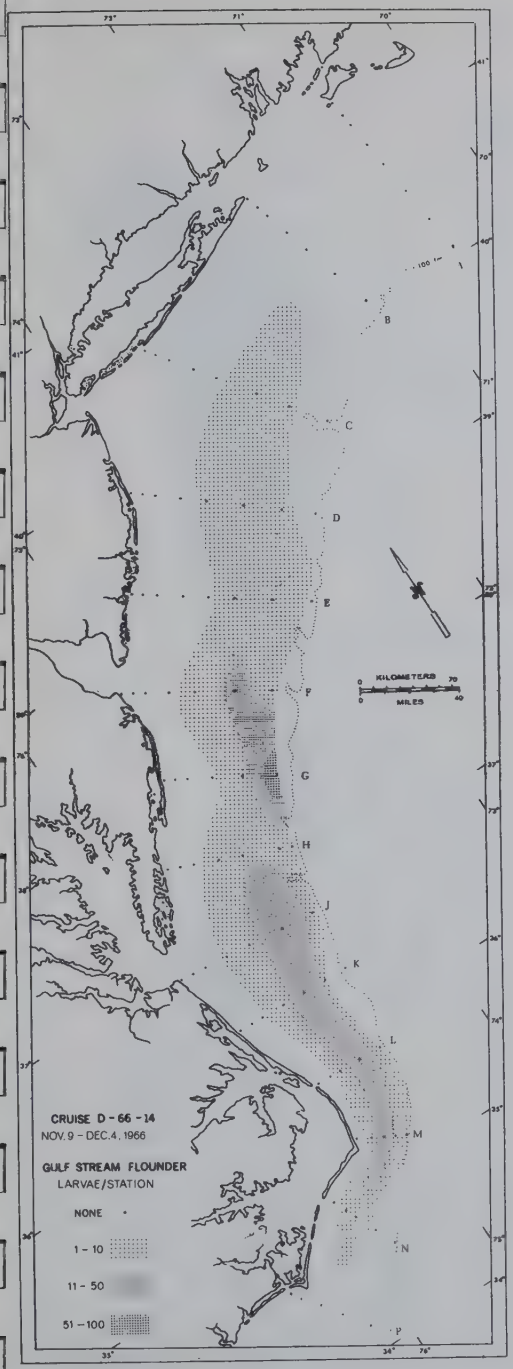


Figure 13.—November to December 1966. Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae.

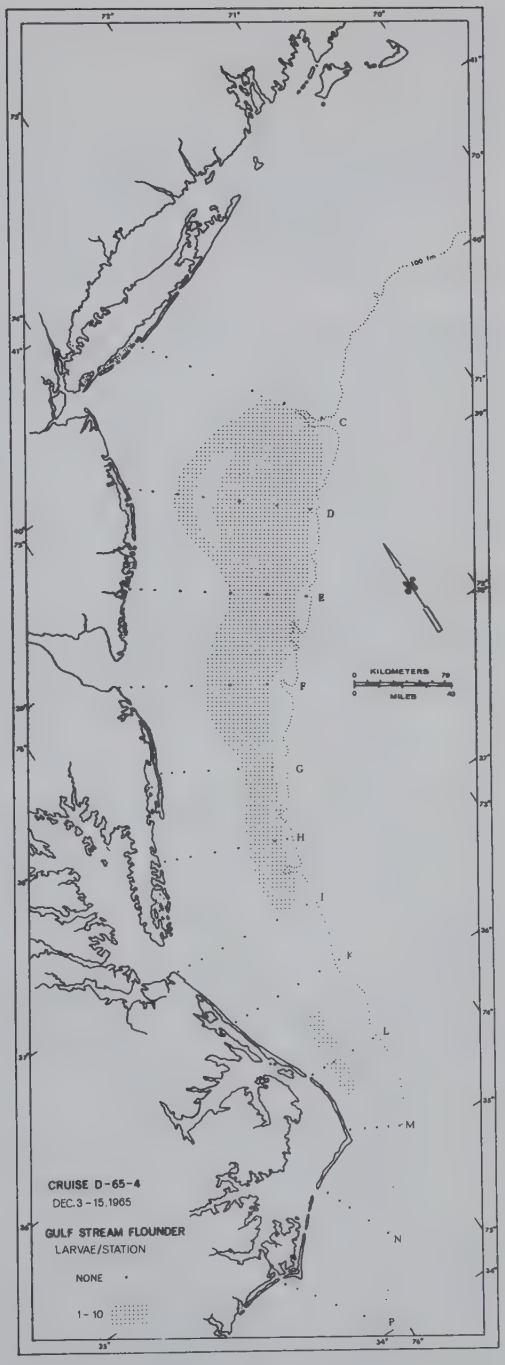


Figure 14.—December 1965. Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae.

their occurrence and extensive size range during early spring cruises suggest that spawning may occur sporadically throughout the year. Richardson and Joseph (1973) reached the same conclusion after examining ovaries of adult Gulf Stream flounder.

We caught larvae throughout the survey area during the spawning season, largely along the outer half of the shelf, i.e., at depths where the adults seem to be most abundant (Fig. 15). Although the distributional patterns of summer and fall catches showed no apparent influence of coastal circulation, the lack of larvae >12 mm off southern New England suggests transport from there southward.

Cyclopsetta fimbriata (Goode and Bean), spotfin flounder.—This warm-water bothid ranges from North Carolina to the Gulf of Mexico and along the Caribbean coasts of Central and South America. Spawning takes place off the west coast of Florida in late spring (Topp and Hoff 1972), but Gutherz (1971), who described the larvae, reported a longer spawning season off our southeast Atlantic coast. His data indicate that spawning begins in April, peaks in June and again in September, and continues to October.

The southern end of our survey area and the northern end of the spotfin flounder's range overlapped between capes Lookout and Hatteras. Although the number of larvae in our collections is small (Table 6), the seasonality of their occurrence agrees closely with that of Gutherz (1971). We caught larvae from April to December, mostly at stations on the seaward half of the shelf where depths exceeded 25 m (Fig. 16). Most of these larvae probably originated south of the survey area and were subsequently transported north by the Gulf Stream.

Etropus microstomus (Gill), smallmouth flounder.—Smallmouth flounder range from New England to Florida (Parr 1931) and into the Gulf of Mexico (Gutherz 1967). Gutherz reported their northern limit as North Carolina, but these small bothid flounders are common in the Middle Atlantic Bight. The larvae are described by Richardson and Joseph (1973).

Spawning might occur throughout the year south of the survey area, because we caught larvae the year-round in the southern part of the survey area. In the bight, however, spawning probably did not begin until June, after which it peaked during summer and early fall. Richardson and Joseph (1973) reported similar results from a series of monthly collections made off Chesapeake Bay.

We considered larvae collected in April between capes Lookout and Hatteras to represent the onset of the 1966 spawning season. Judging from their size and numbers, we assumed they originated somewhere south of Cape Lookout and were transported into the survey area (Table 7). The distribution, sizes, and numbers of larvae collected in May resembled those of April.

The distribution of larvae in June extended northward to Maryland. Although a center of abundance was not evident, most larvae, and most recently hatched larvae, occurred over depths of 15 to 35 m between the eastern shore of Virginia and Cape Hatteras over bottom temperatures of 13° to 17°C. Most of the larvae collected in June were <4 mm and presumably represented recent spawning (Table 7). The northward progression of spring spawning was apparent within the June collections, when larvae <4 mm occurred farther north than those >4 mm. The seaward movement of water off North Carolina would account for the

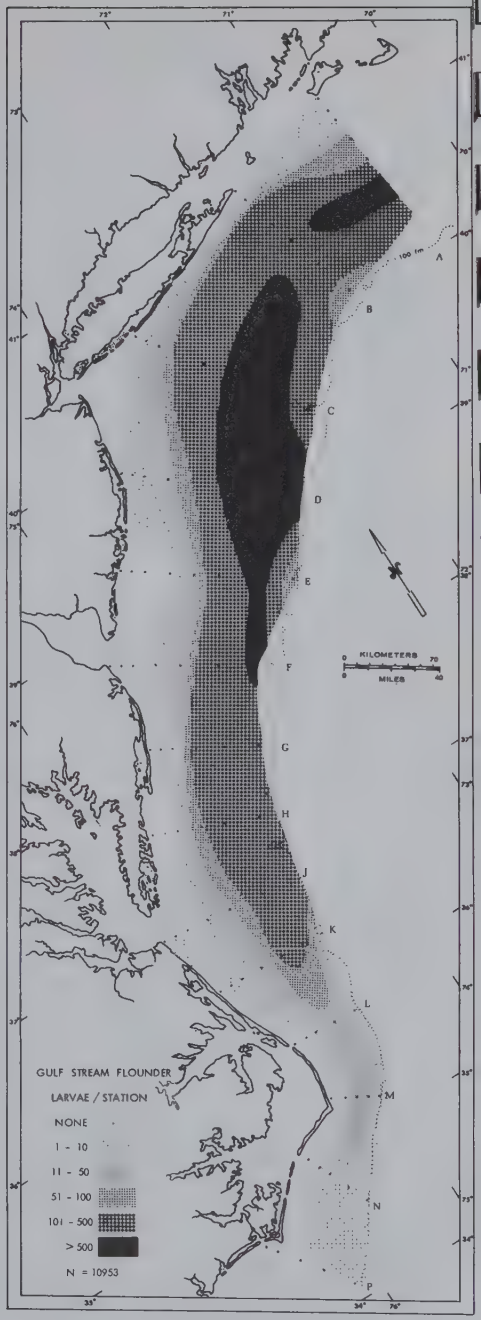


Figure 15.—Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae collected during 1965-66 survey.

Table 6.--The seasonal distribution of spotfin flounder, Cyclopsetta fimbriata, larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date: 66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	Total
	Number of larvae							
2.1- 3.0			1					1
3.1- 4.0		3	2		3			8
4.1- 5.0	1	3	2		6	1		13
5.1- 6.0		1		2	4	1		8
6.1- 7.0		4	1	1	2	1	1	10
7.1- 8.0			1	2	2			5
8.1- 9.0					1	1		2
9.1-10.0					1			1
10.1-11.0	—	—	1	—	—	—	—	1
Total	1	11	8	5	19	4	1	49

Table 7.--The seasonal distribution of smallmouth flounder, Etropus microstomus, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae <4.1 mm represented recent spawning.

Larval length (mm)	Cruise and date: 66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	66-1 Jan.-Feb.	Total
	Number of larvae									
1.1- 2.0			5			1				6
2.1- 3.0		4	47	80		30	26	50		237
3.1- 4.0	3	4	52	362		112	107	153	19	812
4.1- 5.0	1	2	19	415	2	128	81	131	23	802
5.1- 6.0	3	2	7	237	5	82	75	42	15	468
6.1- 7.0	1	2	2	184	1	60	30	26	3	309
7.1- 8.0	1	1		62	2	40	28	18	4	156
8.1- 9.0	1	3		120		36	38	19	1	218
9.1-10.0				74	2	10	18	22	2	128
10.1-11.0	1			38		4	10	2		55
11.1-12.0	1			22	1	17	9	1		51
12.1-13.0				3						3
13.1-14.0										
14.1-15.0	—	—	—	—	—	—	—	—	—	—
Total	12	18	132	1,597	13	520	422	464	67	3,245

rrence of larvae at the more offshore stations near Cape eras, as water depths there exceeded the normal depth e of adult smallmouth flounder (Fig. 17).

Inasmuch as we made our largest catches of larvae late in August, it seems likely that spawning peaked sometime between early July and the middle of August. Larval

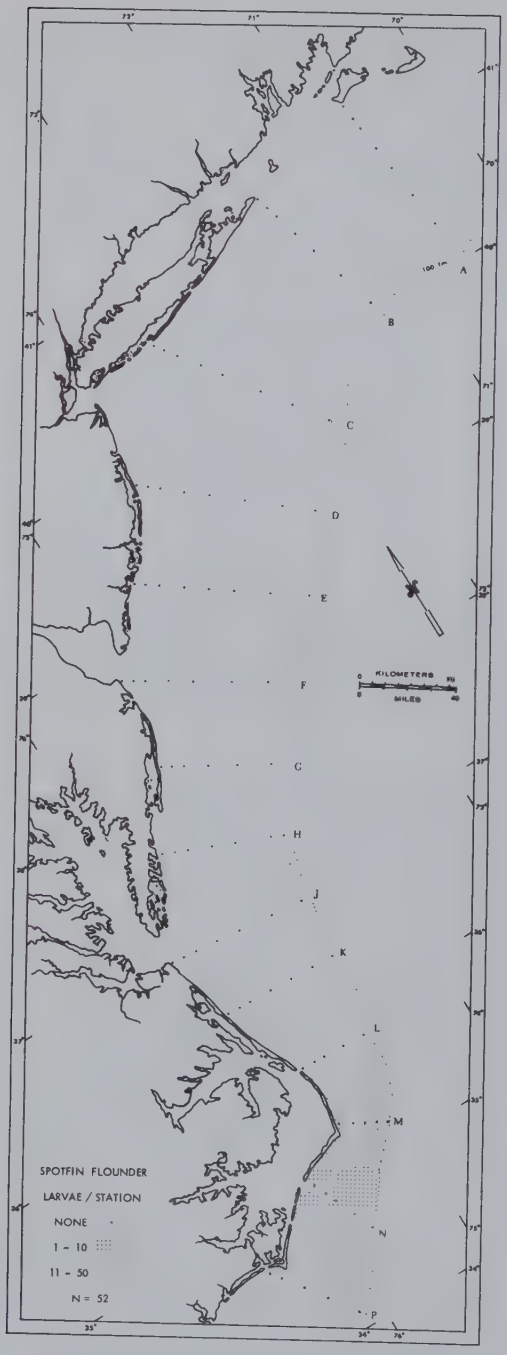


Figure 16.—Distribution and relative abundance of spotfin flounder, *Cyclopsetta fimbriata*, larvae collected during 1965-66 survey.

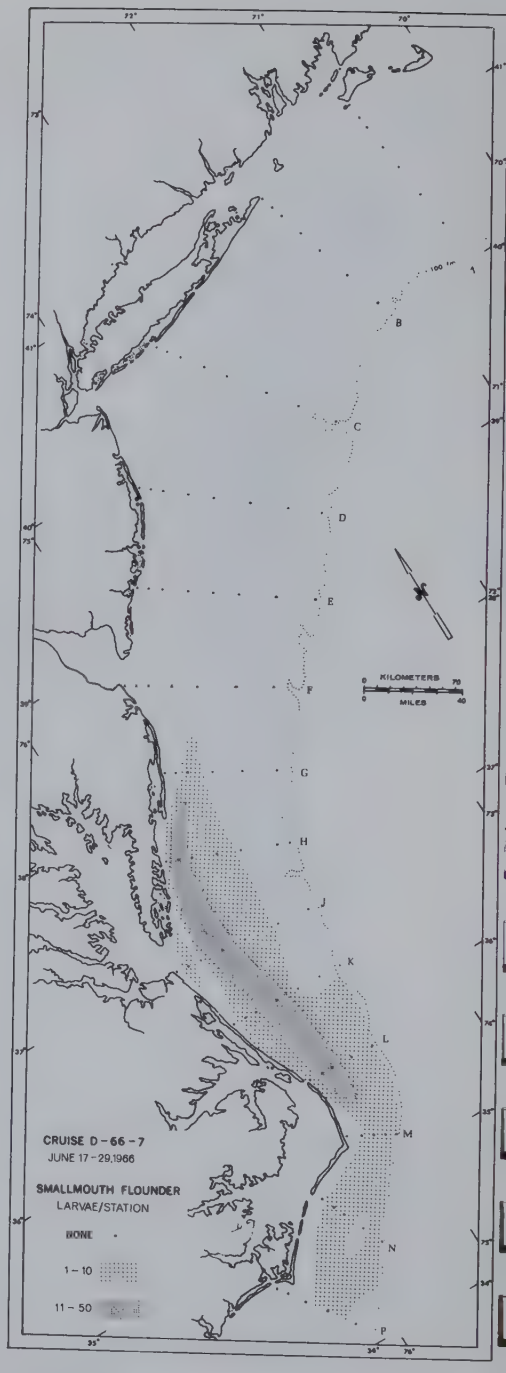


Figure 17.—June 1966. Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae.

ibution was continuous from North Carolina to New , with a large concentration centered off Chesapeake where depths ranged between 15 and 45 m, and a er one off Oregon Inlet, N.C., over depths of about 35 ottom temperatures were 8° to 13°C below the larger e two concentrations and 16°C below the smaller. nt spawning had been most concentrated east of apeake Bay at a depth of 30 m. If spawning reached proportions between the first part of July and the le of August, it must have been largely confined to the ern half of the bight, inasmuch as both recently ed larvae and those >4 mm were most abundant off nia and North Carolina (Fig. 18).

September, when we sampled only the four northern sects, we caught 13 larvae off Long Island and northern Jersey, none of which represented recent spawning. e caught larvae along the entire survey area in October, t at the northernmost transect off southern New and. The center of abundance, much smaller than that ugust, occurred off the outer banks of North Carolina a depth of 35 m and a bottom temperature of 16°C. nt spawning apparently had occurred as far north as astern end of Long Island, but we caught most of the e >6 mm between Maryland and North Carolina, a rn similar to that found in August. Spawning was light of Delaware Bay (Fig. 19).

e distribution of larvae in November extended from auk Point to Cape Lookout but it was interrupted off Jersey, where the cruise started. Recently hatched e were most abundant between capes Hatteras and out, south of observations made in October. Since e <4 mm occurred at only two stations north of Cape ras, we concluded that spawning had ended in the . Water depths of 35 to 340 m and the catch location led conclude that most larvae caught south of Cape ras were transported into the survey area by the Gulf m. We caught some intermediate-sized larvae (4 to 8 off Long Island and northern New Jersey, but nced larval stages (8 to 12 mm) occurred only as far as Maryland (Fig. 20).

y one larva was taken north of North Carolina in mber (1965). Most larvae were taken south of Cape eras, the center of their distribution being between Hatteras and Lookout over depths of 45 to 150 m 21). We concluded that these, like those caught in mber, were transported into the survey area. Al- gh fewer in number, their distribution in January similar to that in December (Fig. 22).

allmouth flounder have an extended spawning season progresses northward in the spring and southward in ll. Although this small bothid is reported from as far as New England (Parr 1931), it appears from our tions that the bight marks its northern limit of ning. We caught larvae from the eastern end of Long d to Cape Lookout, but spawning was most concentrat- om Virginia to North Carolina. No larvae occurred as rth and east as the transect off southern New England. absence of advanced larval stages off New York sts that spawning there was largely unsuccessful, or the small larvae we caught there were subsequently ported southward by currents. Although smallmouth ler and Gulf Stream flounder spawn at the same time r, their respective larval distributions substantiate the mouth's preference for shallow water (see Gutherz Richardson and Joseph 1973) and the more northern of Gulf Stream flounder (see Figs. 23 and 15).

Hippoglossina oblonga (Mitchill), fourspot flounder.—Fourspot flounder inhabit shelf waters as far north as Georges Bank. Although their range extends southward to Florida (Gutherz 1967), trawl records at this laboratory, and our larval collections as far south as Palm Beach, Fla., indicate that they are rare south of Cape Hatteras. The Middle Atlantic Bight encompasses that section of the shelf where fourspot flounder occur in greatest numbers. Their center of abundance lies between southern New England and Delaware Bay, where they reportedly spawn from May to mid-July (Bigelow and Schroeder 1953). The larvae were described by Leonard (1971).

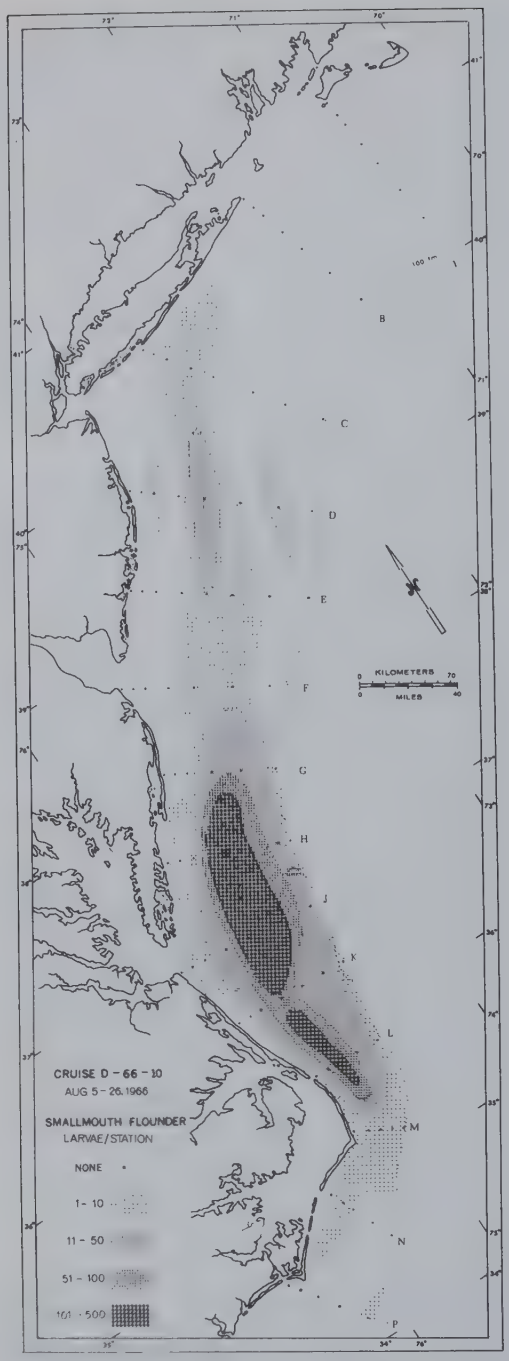
Fourspot flounder had the shortest spawning season of the bothid flounders that spawn in the bight, perhaps a consequence of their more northerly distribution. The season, however, was longer than reported by Bigelow and Schroeder (1953). We caught larvae from May through October, and it appeared from their size that spawning lingered into fall (Table 8).

In June, larvae were scattered along the inner half of the shelf from the outer banks of North Carolina to Delaware, except off North Carolina where they probably were carried seaward by currents (Fig. 24). Most of the larvae were small, <4 mm, none >8 mm. Their size, limited geographic distribution, and the fact that only one was taken during the May cruise suggested that the spawning season was just beginning.

Although we did not sample during July, it appears likely that spawning was maximal then. By August, larvae were distributed from North Carolina to southern New England. There were two centers of abundance: one midway out on the shelf off New Jersey over depths of 30 to 40 m, the other on the outer part of the shelf off southern New England over depths of 60 to 80 m. A lesser concentration occurred east of Chesapeake Bay near the edge of the shelf. Most larvae comprising the two major centers of abundance were small and presumably had been spawned nearby. Bottom temperatures near the two concentrations, 8.6° and 9.0°C, respectively, were lower than those observed where we caught larvae in June but warmer than in May, when we first caught young fourspot flounder. Although larvae 4 to 8 mm had a distribution similar to that of the smaller size group, larvae 8 to 12 mm were caught mostly between New Jersey and North Carolina, reflecting the earlier spawning evident in our spring catches (Fig. 25). We caught three larvae >12 mm off Virginia.

When we sampled only the four northernmost transects in mid-September, larvae were most abundant off New Jersey and Long Island, but concentrations were not as great as those found on the previous cruise (Fig. 26). Recently spawned larvae were most numerous off Long Island over depths of 55 to 75 m and bottom temperatures between 7.9° and 8.5°C. Most of the larvae were 4 to 8 mm.

The distribution of larvae in October extended from eastern Long Island to Chesapeake Bay. A single concentration reached from southern New Jersey to Maryland over depths between 25 and 55 m. Recently hatched larvae, those<4 mm, predominated at the center of abundance over 6.2°C bottom water. Those 4 to 8 mm were scattered throughout the area of occurrence (Fig. 27). The reduced catch and receding areal extent of larval occurrence in October indicated that spawning had peaked during the summer. The absence of larvae on the following cruise confirmed the October results.



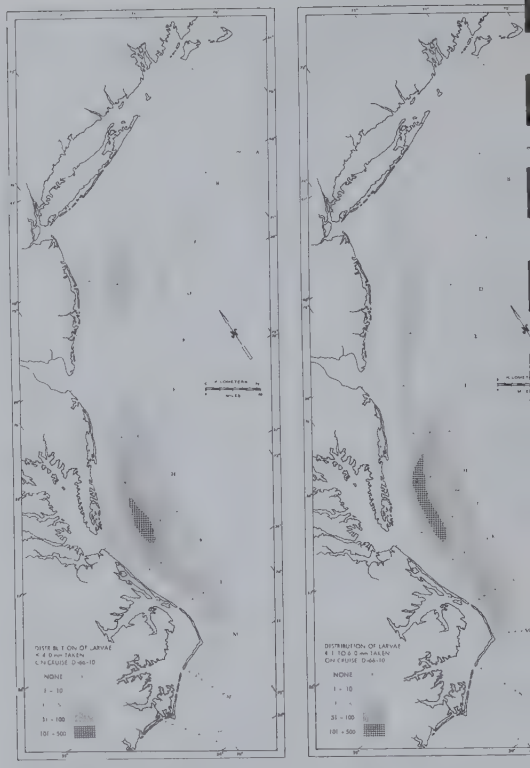


Figure 18.—August 1966. Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top <4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, 8.1 to 12.0 mm.

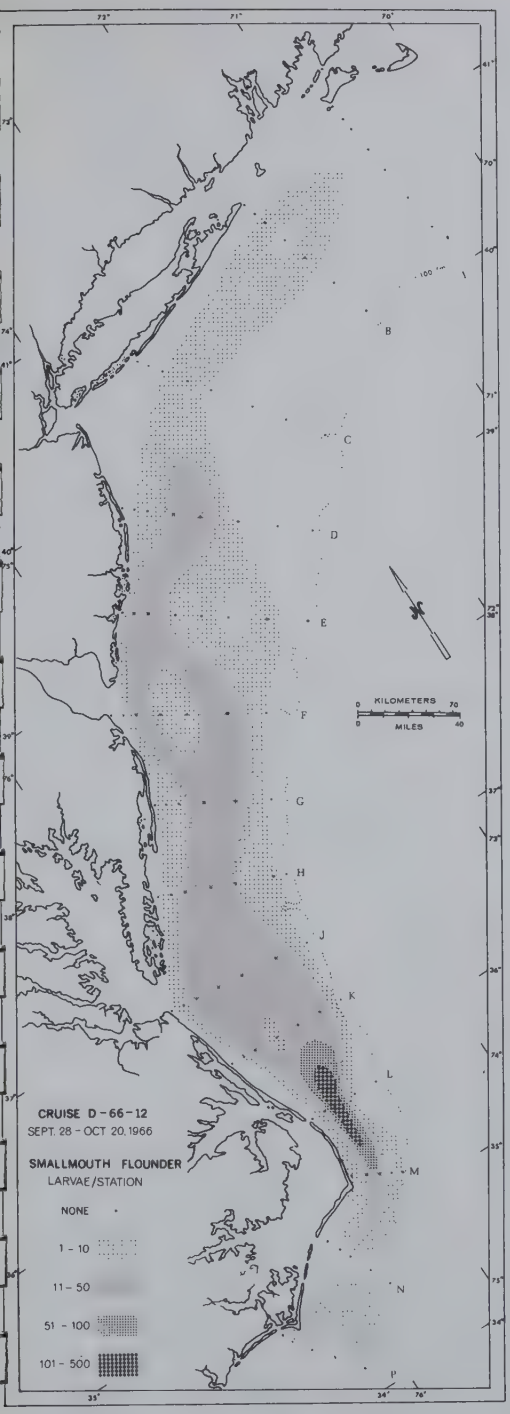
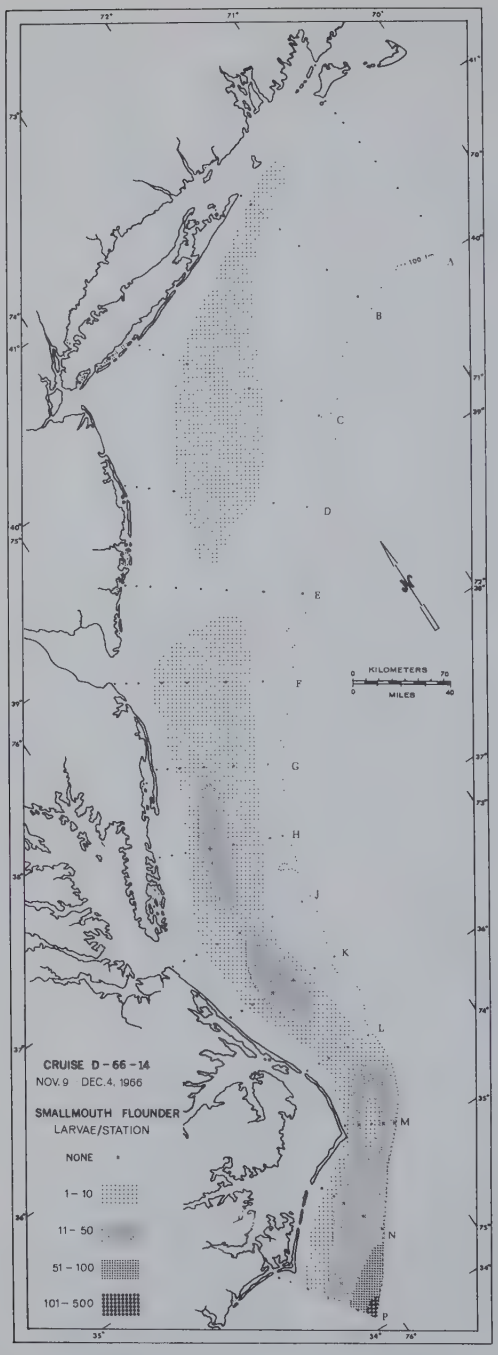


Figure 19.—September to October 1966. Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, 8.1 to 12.0 mm.



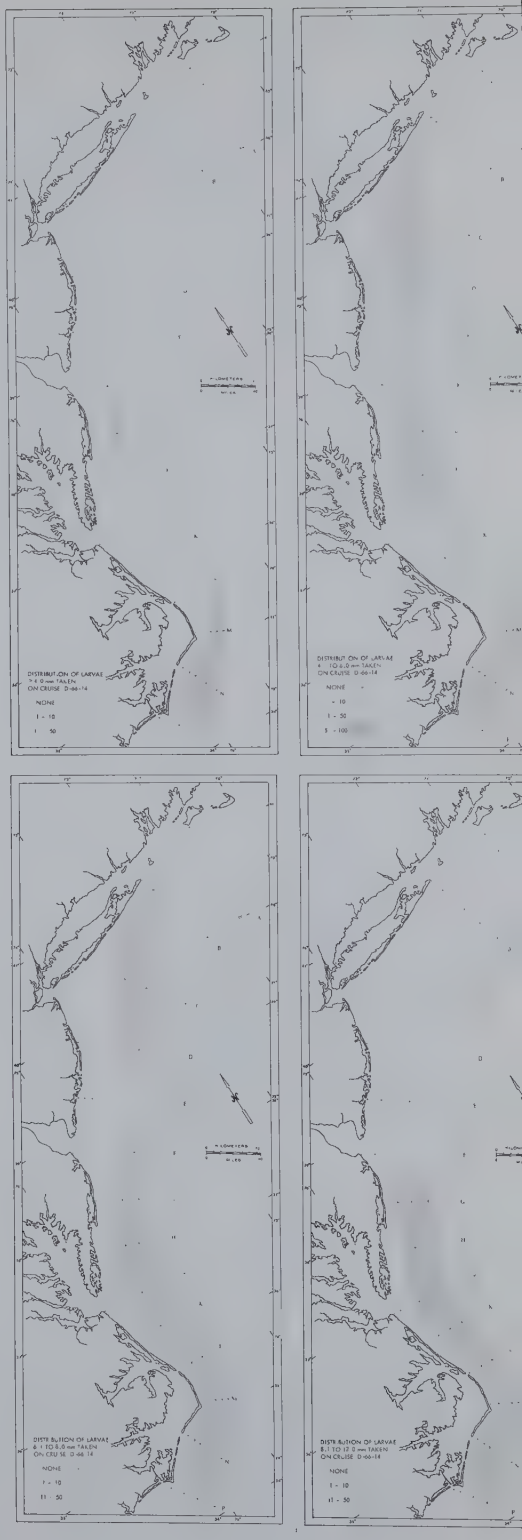
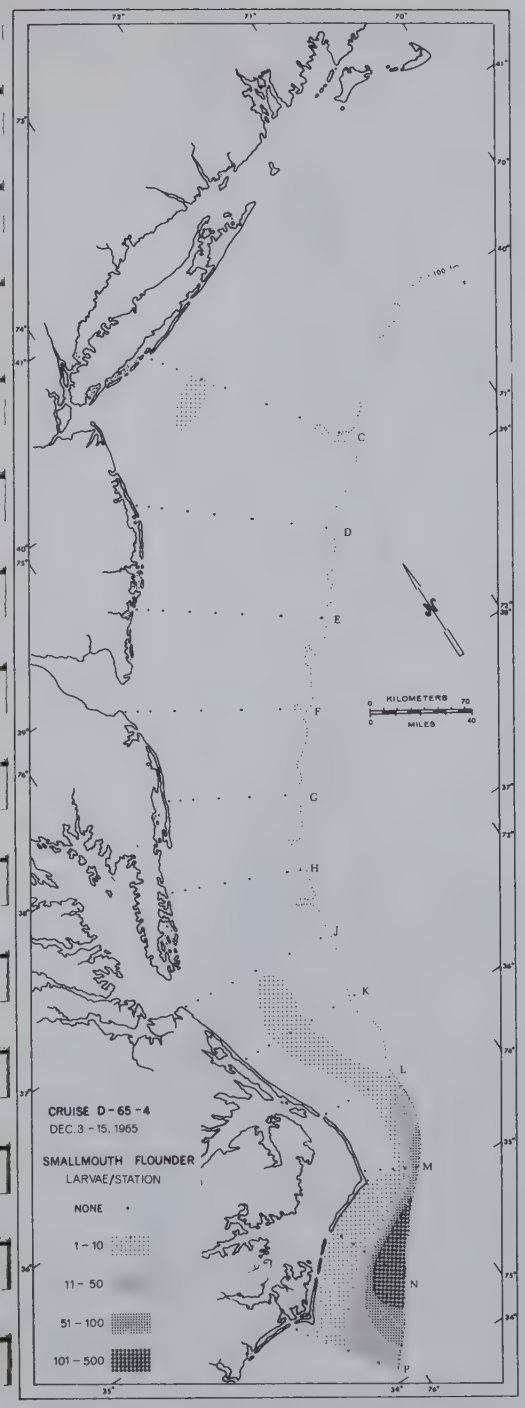


Figure 20.—November to December 1966. Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, 8.1 to 12.0 mm.



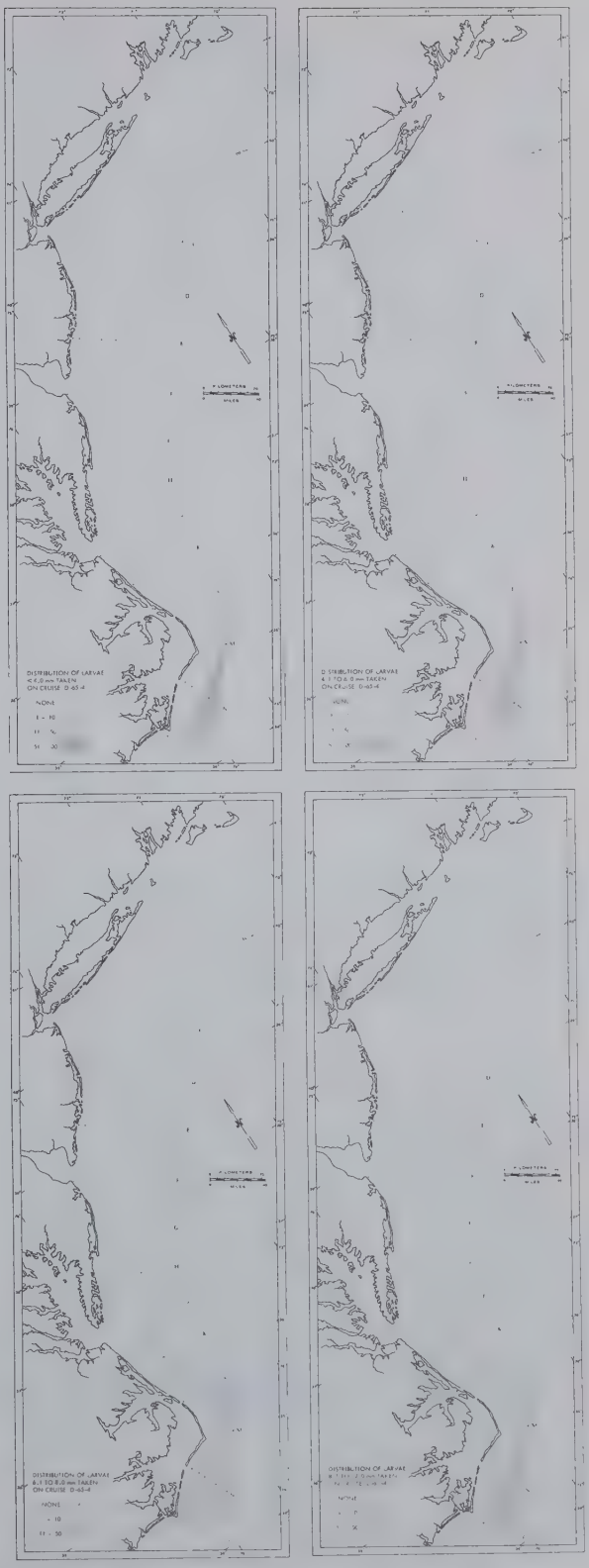


Figure 21.—December 1965. Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, 8.1 to 12.0 mm.

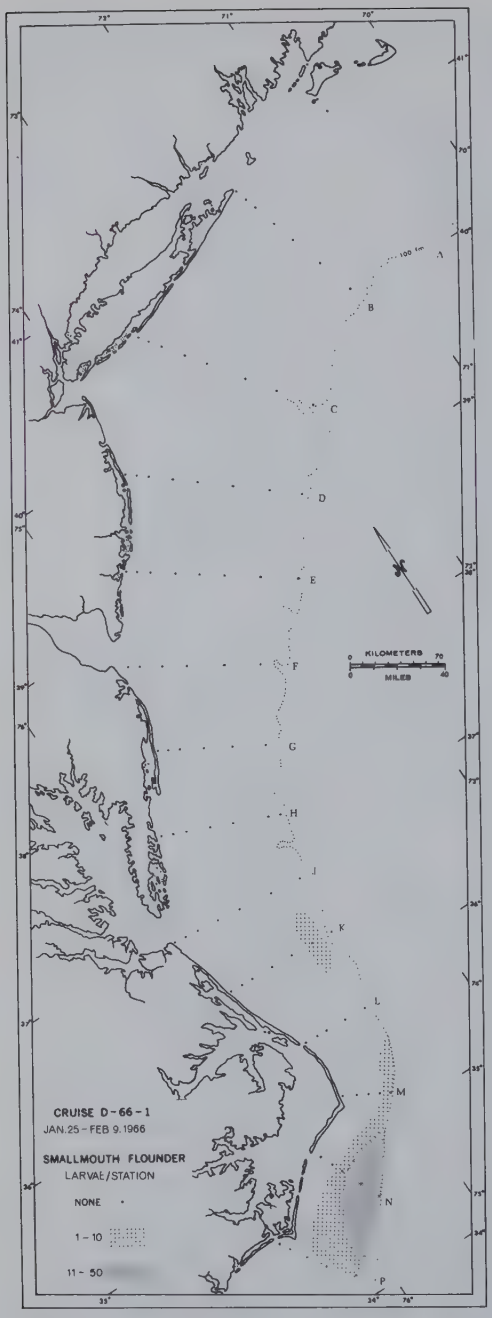


Figure 22.—January to February 1966. Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae.

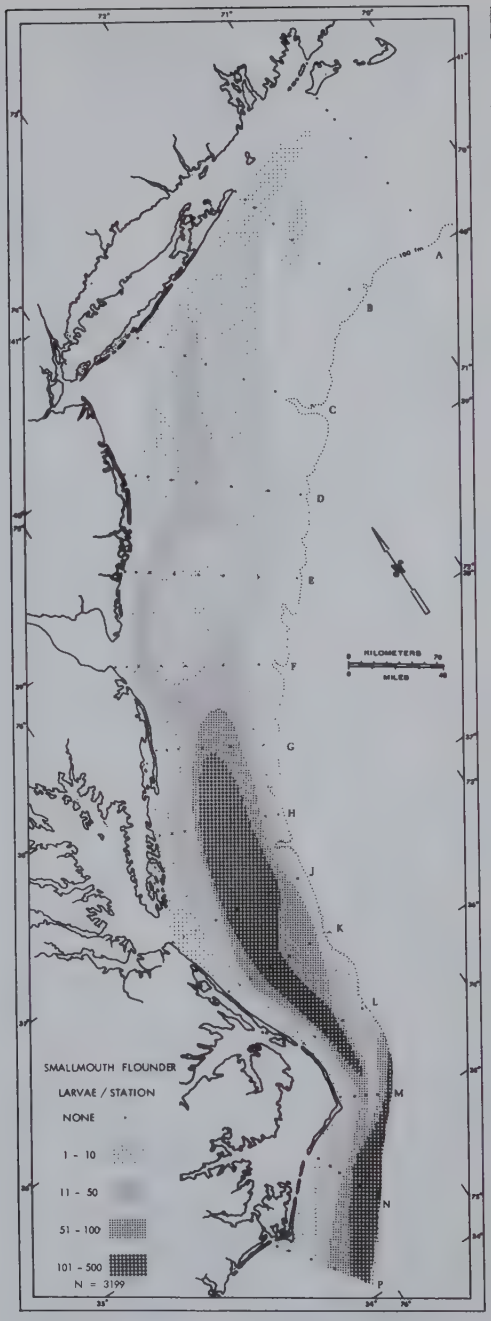


Figure 23.—Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae collected during 1965-66 survey.

Table 8.--The seasonal distribution of fourspot flounder, Hippoglossina oblonga, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae < 4.1 mm represented recent spawning.

Larval length (mm)	Cruise and date: 66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	Total
	Number of larvae					
1.1- 2.0			2			2
2.1- 3.0	1	19	208	29	45	302
3.1- 4.0		22	413	113	185	733
4.1- 5.0		15	349	183	121	668
5.1- 6.0		3	229	125	71	428
6.1- 7.0		4	120	48	56	228
7.1- 8.0			41	3	24	68
8.1- 9.0			14	1	9	24
9.1-10.0			5		1	6
10.1-11.0			4		2	6
11.1-12.0			4			4
12.1-13.0			1			1
13.1-14.0			1			1
14.1-15.0			1			1
Total	1	63	1,392	502	514	2,472

The seasonal distribution of fourspot flounder larvae characterized that of most spring spawners by advancing from south to north as water temperatures increased. Additional evidence of the influence of temperature was apparent in the seaward shift in spawning as the season progressed and offshore waters warmed. Although spawning began nearshore off Virginia and North Carolina, the distribution of all fourspot flounder larvae indicated that most spawning took place along the northern half of the bight at temperatures between 6.2° and 9.0°C and in depths between 35 and 80 m (Fig. 28). The area and depths of major larval concentrations correspond with the reported depth distribution and center of abundance for adults (Bigelow and Schroeder 1953). We seldom caught larvae >8 mm, probably because they were unavailable to our gear. Because we caught metamorphosing specimens of other flatfish larvae that occurred regularly in our collections, we attribute the scarcity of fourspot flounder >8 mm to a change from a pelagic to a largely demersal life at about 8 mm, although metamorphosis is not complete at 12 mm (Leonard 1971).

Monolene sessilicauda Goode, deepwater flounder.—Deepwater flounder range from New England to Florida and into the Gulf of Mexico (Gutherz 1967). Our identification of larvae is based on the description of larvae from the eastern Gulf of Mexico (Futch 1971), the reported distribution of adults by Gutherz (1967), and on fin ray counts from our largest specimen.

We caught only six larvae: one (7.0 mm) in April off Hatteras Inlet, three (7.1, 8.6, 10.1 mm) in June off Cape Hatteras, and one each (11.8 and 19.3 mm) in August and September off New Jersey. All six were caught near the edge of the shelf. Because of their size and infrequent occurrence, we concluded that the larvae had originated outside the survey area.

Paralichthys dentatus (Linnaeus), summer flounder.—Summer flounder range from Maine to Florida (Gutherz 1967), but they are not common north of Cape Cod or south of South Carolina. Their geographic distribution resembles that of windowpane, *Scophthalmus aquosus*, and fourspot flounder, mentioned previously, in that the center of abundance lies within the bight, and they must be considered more of a temperate latitude species than most bothids. Because of the importance of summer flounder to both commercial and sport fishermen in the bight, data on eggs and larvae collected during the survey were previously published (Smith 1973). The distribution of summer flounder larvae is presented in this paper to provide a comprehensive report, which includes all identified flatfish larvae collected during the survey. Summer flounder larvae were described by Smith and Fahay (1970).

Spawning began in late summer and continued to midwinter. There was a pronounced southerly shift in spawning and distribution of larvae as the season progressed. North of Chesapeake Bay, spawning occurred from September to December; south of the bay, from

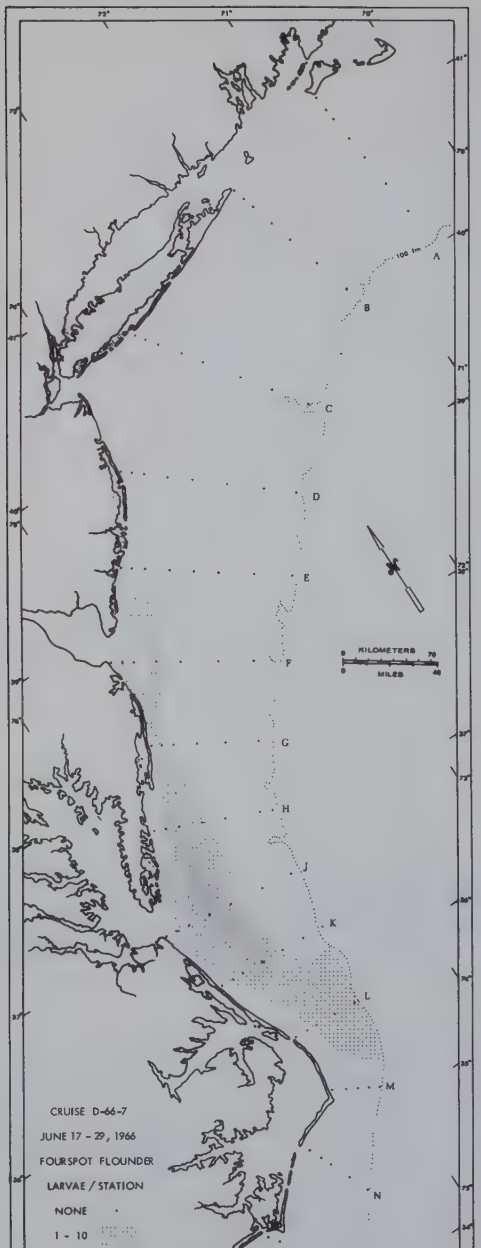


Figure 24.—June 1966. Distribution and relative abundance of fourspot flounder, *Hippoglossina oblonga*, larvae.

November to February. Although most spawning occurr at temperatures between 12° and 19°C, both eggs a larvae seemed to withstand a much wider range c temperature.

Larvae were collected first off Long Island and northe New Jersey during the abbreviated cruise in September Their small size and restricted distribution indicated tha spawning had recently started, probably during the fir week in September (Table 9).

We made our largest catch of larvae in October, althoug spawning occurred only in the northern half of the surve area. The distribution of both eggs and larvae seemed to restricted to nearshore waters by the cold cell of bott water that stretched from Long Island to Maryland. Withi this restricted area, the distribution of larvae wa continuous from southern New England to Virginia, w concentrations off Martha's Vineyard, off Long Island a northern New Jersey, and off Delaware Bay. Spawning w most intense off New Jersey at depths of 20 to 48 m (Smit 1973). Larvae <4 mm were abundant off New Jersey ov 16.8°C bottom water and off Delaware Bay over 6.8 bottom water, where they had apparently drifted fro spawning grounds nearer shore. Eggs were abundant at th adjacent inshore station over bottom temperatures of 14° but absent from the location off Delaware Bay, where t small larvae were concentrated (Smith 1973). The d tributions of larvae in size groups of 4.1 to 6.0 mm and 6. to 8.0 mm extended from Cape Cod to northern Virgini Larvae >8 mm were caught off Long Island and southe New England, which substantiates earlier spawning the than in more southern parts of the bight (Fig. 29).

From mid-November through early December, larv occurred throughout the survey area. Based on t distribution of eggs, spawning was centered off Maryla and northern Virginia and off the outer banks of Nort Carolina (Smith 1973), but larvae of all four size groups we most abundant off Long Island and New Jersey. The cent of abundance consisted mostly of larvae 4.1 to 6.0 mm lo It was located off New Jersey over a bottom temperature 10.5°C and a depth of 45 m (Fig. 30).

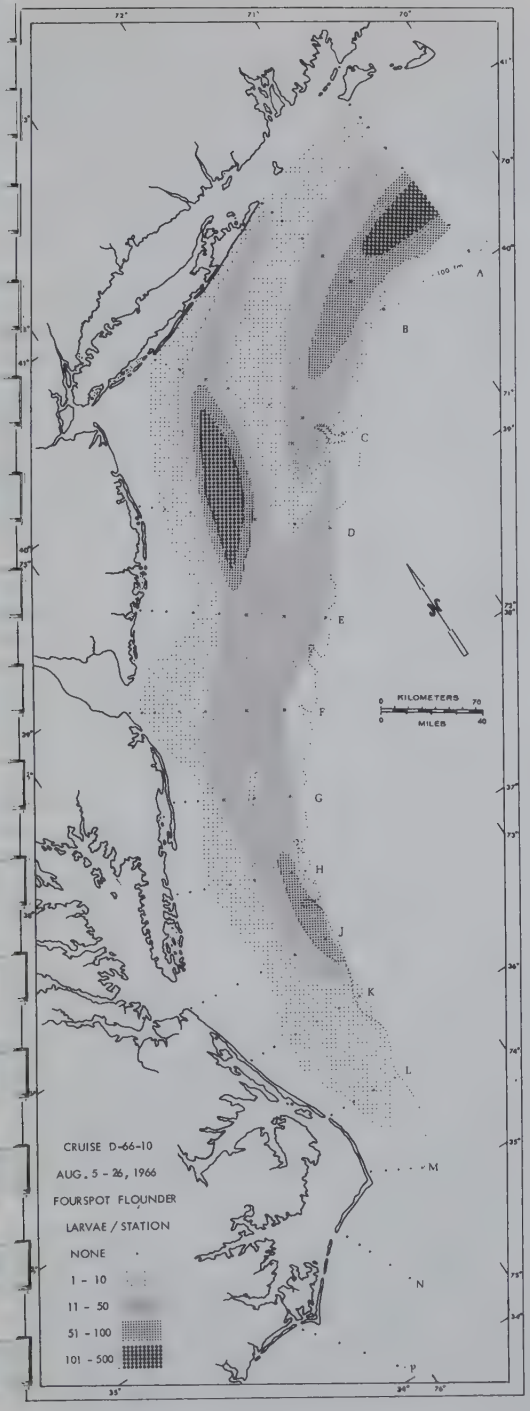
Although in December (1965) we caught larvae throug out the area sampled, the distribution of eggs was limited waters off North Carolina (Smith 1973). Most newly hatche larvae were caught off North Carolina, but representativ of the larger size categories were most abundant off N Jersey (Fig. 31).

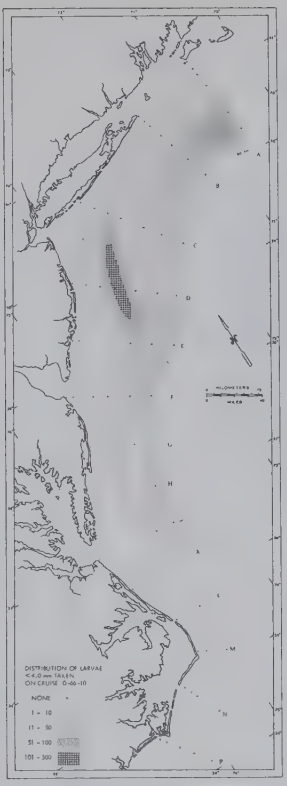
By January, the number of larvae diminished, and, wi the exception of a few, their distribution was limited to t area south of Cape Hatteras (Fig. 32). We caught four eg the last of the season, at the seaward station off Ca Lookout.

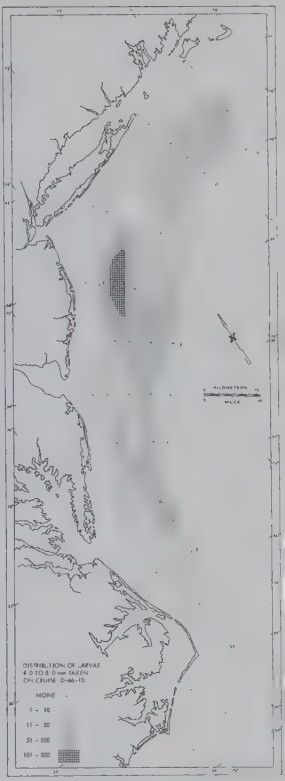
In April, we caught larvae only in the extreme southe part of the survey area (Fig. 33). Most were >8 mm and h started to metamorphose (Table 9). In May, we caug seven larvae off North Carolina, which we assum represented remnants of late spawning. None were caug on the following cruises in June and August.

Larvae occurred throughout the survey area during course of the spawning season. Their distribution shift southward as the season progressed. The most importa spawning grounds were off New York and New Jersey early fall and, to a lesser extent, off North Carolina in l fall (Fig. 34).

Although spawning takes place at sea, young-of-the-ye are found in estuaries (Smith 1973). Because the juveni







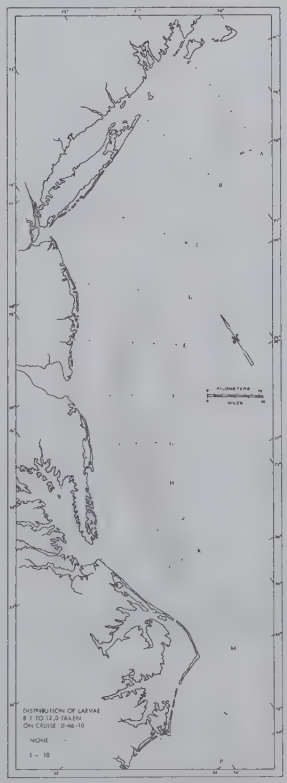


Figure 25.—August 1966. Distribution and relative abundance of fourspot flounder, *Hippoglossina oblonga*, larvae (left) and (right) their distribution and relative abundance by size groups. Top <4.0 mm, 4.0 to 8.0 mm; bottom 8.1 to 12.0 mm.

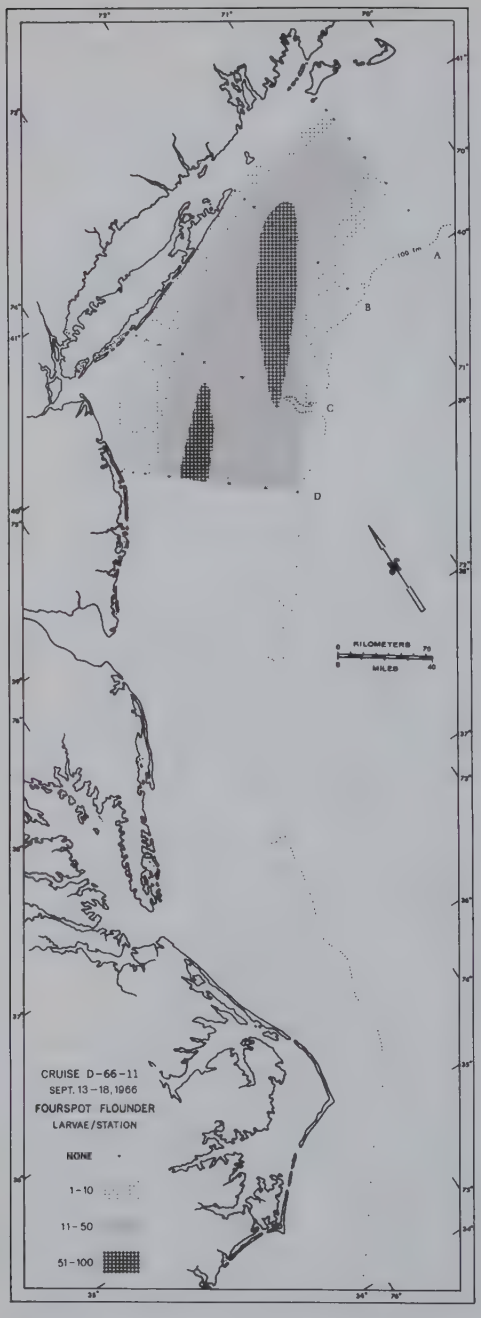


Figure 26.—September 1966. Distribution and relative abundance of fourspot flounder, *Hippoglossina oblonga*, larvae.

are found only in estuaries, summer flounder are conside estuarine dependent. Their tolerance to a wide range o both temperature and salinity indicates that they ar physiologically adapted to withstand the extreme variati in temperature and salinity characteristic of our estuarie temperate latitude. Young have been collected from water that ranged in temperature between 2° and 31.2°C an salinity from 0.02 to 37‰ (Tagatz and Dudley 19 Williams and Deubler 1968). Deubler and White (1962) k young summer flounder in water with a salinity of 40‰.

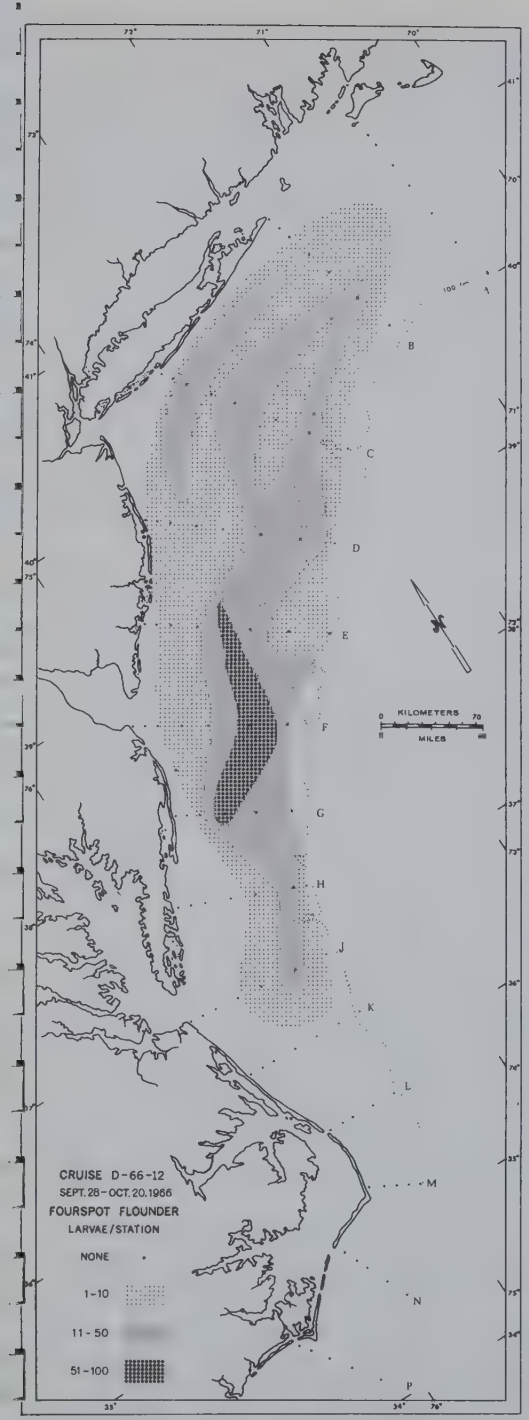
Paralichthys spp.—Four species of *Paralichthys* o along our eastern seaboard. We have discussed distribution of *P. dentatus* larvae which we cau throughout the survey area. Of the other three, *lethostigma* Jordan and Gilbert and *P. albigutta* Jordan Gilbert occur regularly, *P. squamilentus* Jordan and Gil rarely, as far north as North Carolina. Their larvae have been described. Using a combination of fin ray an vertebral counts, we identified advanced larval stages o *lethostigma* and *P. albigutta* in our collections. Small lar without the full complement of ossified parts could not identified beyond the generic level, so we treated the enti lot as *Paralichthys* spp. Although we did not recog larvae of *P. squamilentus*, it probably spawns as far nort the Carolinas. Juveniles have been collected in estuarie both North and South Carolina (Rothschild and Deubl 1960; Bearden 1971).

All four species spawn in fall and early winter. We ca *P. dentatus* larvae, mostly north of Cape Hatteras, f September to May. South of the cape, larvae *Paralichthys* spp. occurred from November into A Spawning apparently peaked in late November or e December, as we made our largest catch of larva mid-December (Table 10). Larvae were not abundant at an of the stations south of Cape Hatteras, but most of th that we collected were on the outer half of the shelf. Son the larvae probably represented local spawning, w others were transported into the survey area from spawnin grounds to the south (Fig. 35).

Scophthalmus aquosus (Mitchill), windowpane.—W dowpane range from Maine to Florida (Gutherz 1967), b their distribution north of Cape Cod is restricted to isolate locations (Bigelow and Schroeder 1953). The Mi Atlantic Bight is the area where windowpane occu greatest numbers. Trawl records at this laboratory indica that the bulk of the population inhabits coastal waters fro southern New England to Chesapeake Bay. Larval st were described by Moore (1947), Bigelow and Schro (1953), and Colton and Marak (1969).

North of Cape Cod, spawning occurs in spring an summer (Bigelow and Schroeder 1953). Perlmutter (1 reported that the spawning season is similar in Long Is Sound, with maximum egg production from late May mid-June. Wheatland (1956), however, reported a sp spawning season in Long Island Sound in 1952 and 1953. collected eggs and larvae from late April through July from mid-September through late October and ear November.

Our catches indicate that, while spawning conti throughout most of the year, it was not a year-round e anywhere in the survey area, but shifted seasonal Spawning began in April south of Chesapeake Bay, reache its peak in May, and ended by June. It advanced north to New Jersey and New York during the summer but di



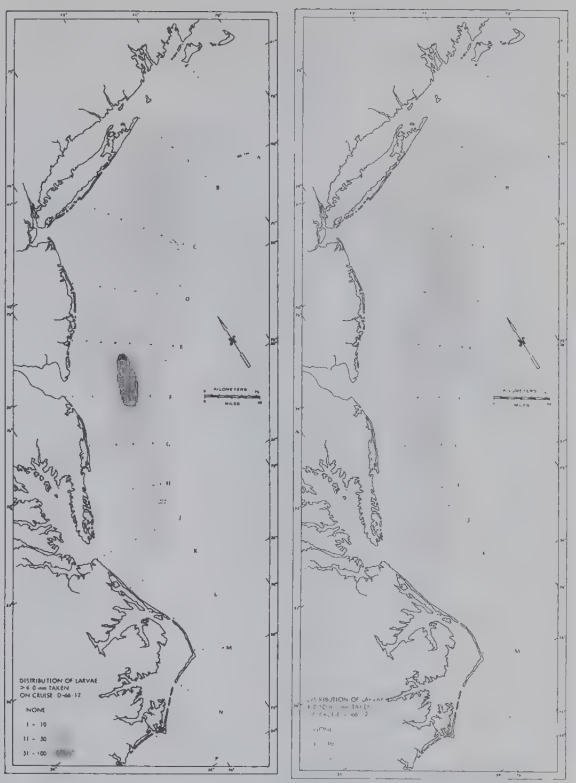


Figure 27.—September to October 1966. Distribution and relative abundance of fourspot flounder, *Hippoglossina oblonga*, larvae (left) and (right) their distribution and relative abundance by size groups. Top <4.0 mm, 4.0 to 8.0 mm.

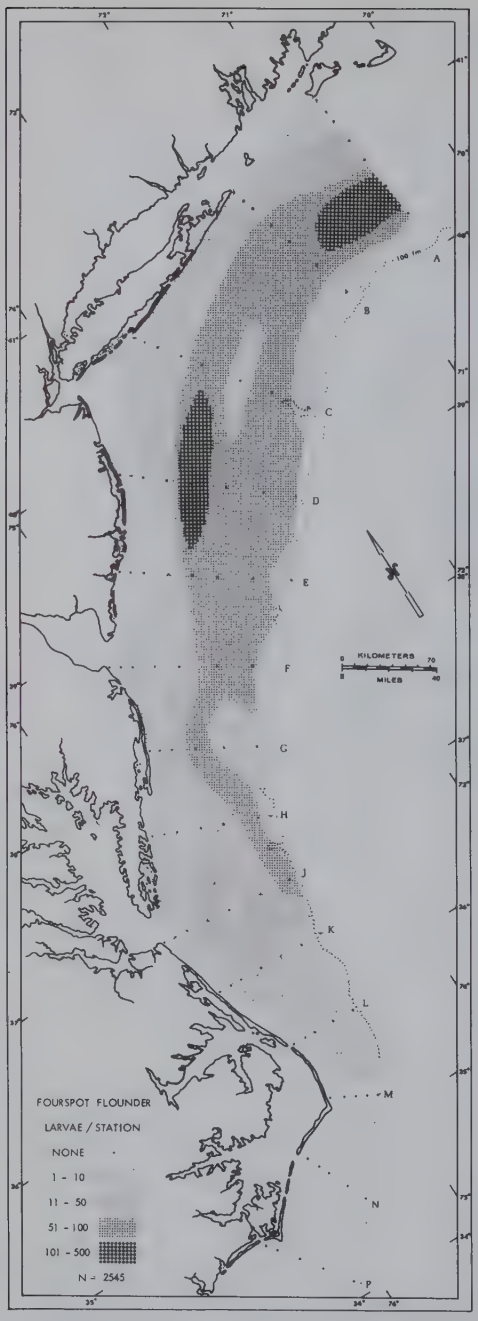


Figure 28.—Distribution and relative abundance of fourspot flounder, *Hippoglossina oblonga*, larvae collected during 1965-66 survey.

peak until fall; and, at that time, it recommenced off Virgi and North Carolina.

Larvae first appeared in April, when we caught newly hatched specimens at a few nearshore stations off Virgi and North Carolina over bottom temperatures of 8° to 13 In May, their distribution extended northward to New Jersey, with concentrations off Virginia and North Carolina Most larvae were small; only eight were >6 mm (Table 1 Bottom temperatures at the two areas of maxim abundance ranged from 9° to 12°C. There was a seaward sweep in the distribution of larvae off North Carolina tha probably resulted from coastal circulation (Fig. 36).

Spawning was light in June, but some newly hatch larvae were collected in the northern half of the survey are (Table 11). With few exceptions, larvae were restricted t the nearshore area over bottom temperatures between and 14°C. The cold mass of bottom water off Long Isla and New Jersey apparently restricted either the seawa distribution of adults or the offshore limits of spawning Spawning ceased in the southern half of the bight in Ju perhaps because the 16° to 17°C bottom temperatures t prevailed there were too warm (Fig. 37).

In August, spawning was again light and restricted t waters off Long Island and southern New Englan shoreward of the cold cell (Fig. 38). The distribution larvae in September was similar to that in August, but so spawning evidently took place off New Jersey in wate deeper than that noted during the June cruise (Fig. 39).

Spawning peaked in the northern part of the survey a in October. We caught specimens at all but the seaw stations on transects between Maryland and southern Ne England, mostly over depths of 20 to 40 m. A large center abundance, consisting of small larvae, extended fr Delaware Bay to Long Island, where bottom temperatu were between 9° and 16°C (Fig. 40). Despite the mos seaward occurrence to date, the distribution of larva resembled the June and August results, in that the offsh edge of their center of abundance was closely alined with inshore edge of the cold cell.

On the following cruise in November and early December the distribution of larvae was continuous from eastern L Island to North Carolina, but the center of abundan consisting mostly of small larvae, remained off New Jerse over bottom temperatures between 10° and 12°C. Althoug spawning was light in comparison with what we observed in May, it evidently recommenced off No Carolina, where we caught larvae <4 mm for the first tim since the spring cruises (Fig. 41). Bottom temperature dropped since the previous cruise to 14°C, where recently hatched larvae occurred off the outer banks North Carolina.

We made the biggest catch in December (1965), when th distribution of larvae was continuous from Long Island, northernmost transect on the cruise, to Cape Lookout (Ta 11). Based on the distribution of larvae <4 mm, rece spawning activity remained centered off New Jersey ove bottom temperatures between 8° and 10°C, but spawn occurred along the entire survey area (Fig. 42). distribution of specimens >6 mm was restricted to wate between Maryland and Long Island, suggesting tha spawning recommenced south of Chesapeake Bay during late fall of 1965, as it did in 1966.

Spawning apparently ended abruptly. By late Janua when bottom temperatures dropped to less than 4°C alon the inner half of the shelf, where spawning occurred earli we caught only five larvae.

Table 9.--The seasonal distribution of summer flounder, Paralichthys dentatus, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae < 4.1 mm represented recent spawning.

Larval length (mm)	Cruise and date							Total
	66-11 Sept.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	66-1 Jan.-Feb.	66-3 Apr.	66-5 May	
	Number of larvae							
2.1- 3.0	1	36	8	11				56
3.1- 4.0	9	430	70	140	11	3		663
4.1- 5.0	4	320	126	146	10	1		607
5.1- 6.0	1	200	94	162	4	3		464
6.1- 7.0		124	53	168	4	3	1	353
7.1- 8.0		34	39	94	2	4		173
8.1- 9.0		9	30	50	10	13	1	113
9.1-10.0			12	22	8	7	2	51
10.1-11.0		1	19	12	4	4		40
11.1-12.0			6	5	1	1	2	15
12.1-13.0			2	2	1		1	6
13.1-14.0	—	—	—	2	—	—	—	2
Total	15	1,154	459	814	55	39	7	2,543

Table 10.--The seasonal distribution of Paralichthys spp. larvae by size (excluding P. dentatus). Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date				Total
	66-14 Nov.-Dec.	65-4 Dec.	66-1 Jan.-Feb.	66-3 Apr.	
	Number of larvae				
2.1- 3.0		6	1		7
3.1- 4.0	2	19	1		22
4.1- 5.0		13	5	3	21
5.1- 6.0		18	1		19
6.1- 7.0	1	9			10
7.1- 8.0		2	1	1	4
8.1- 9.0		1		1	2
9.1-10.0	—	1	—	—	1
Total	3	69	9	5	86

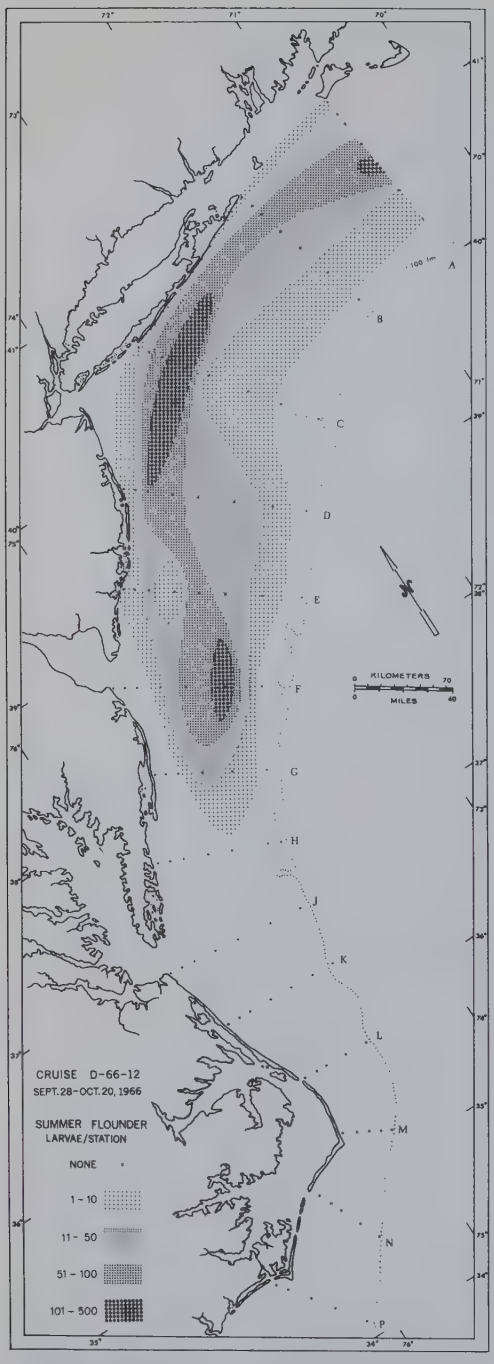


Figure 29.—September to October 1966. Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, >8.0 mm.

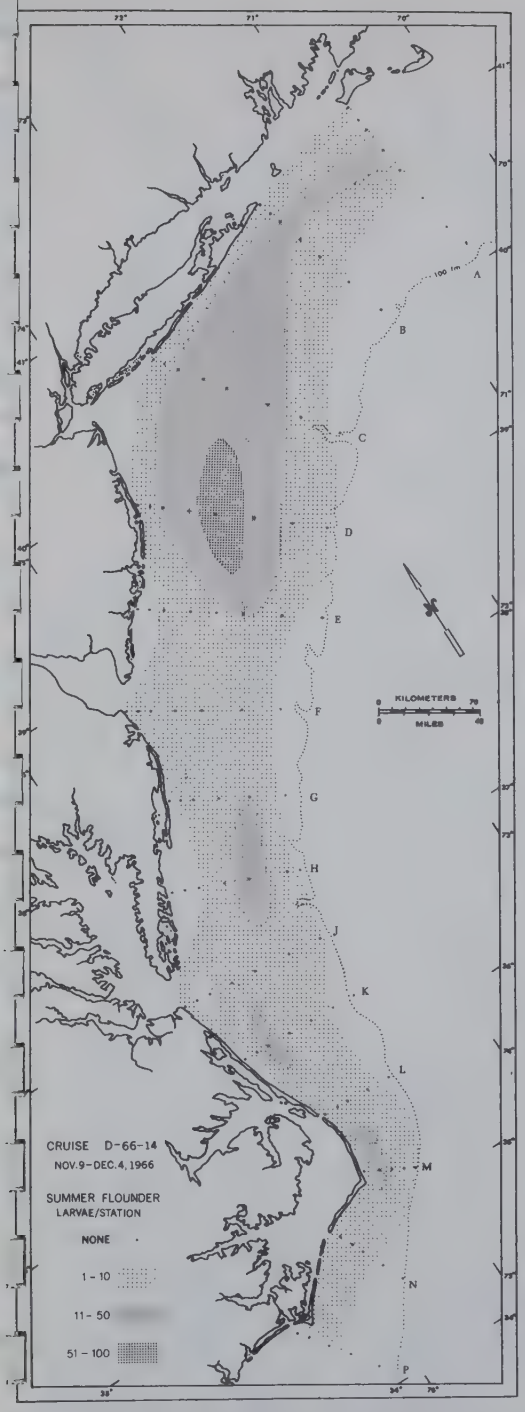
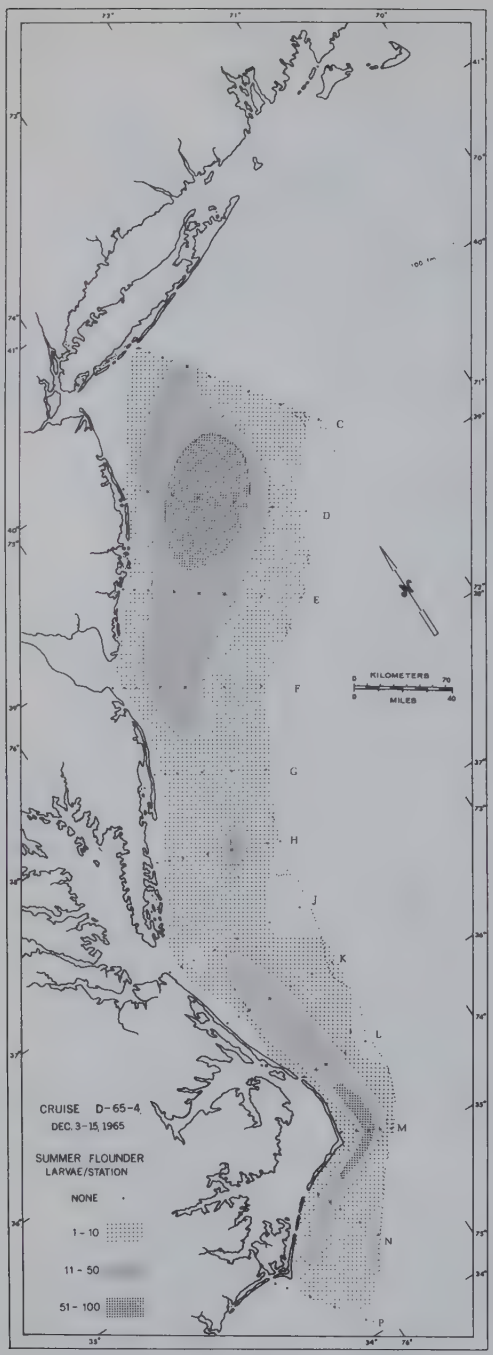


Figure 30.—November to December 1966. Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, >8.0 mm.



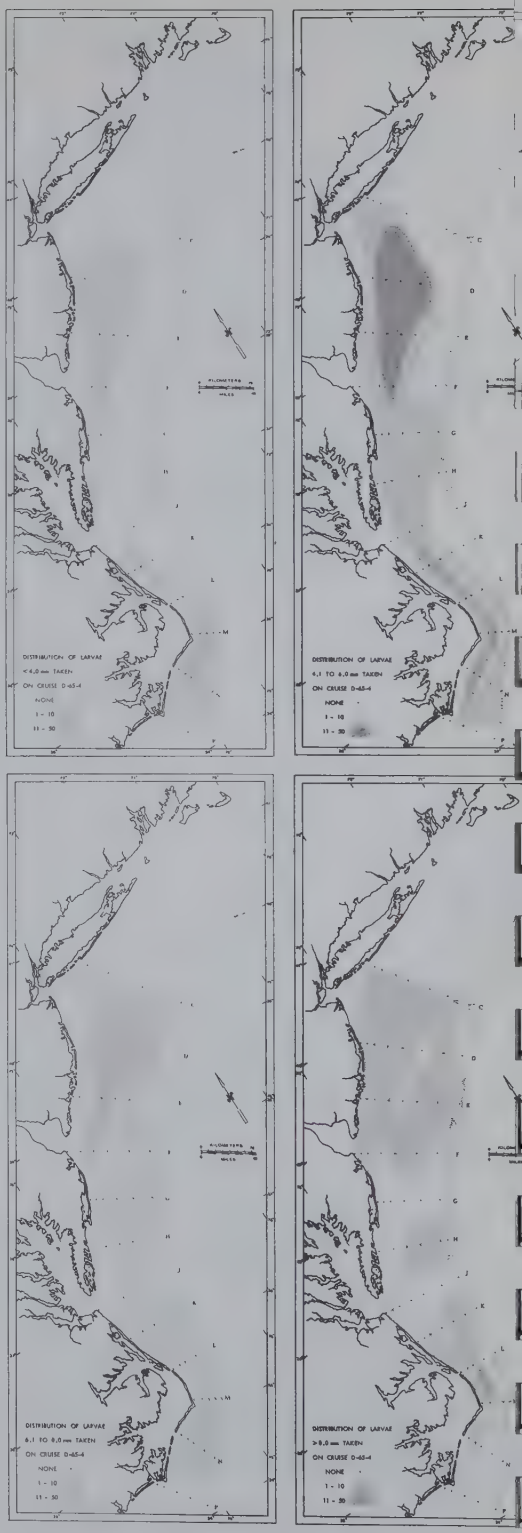


Figure 31.—December 1965. Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, >8.0 mm.

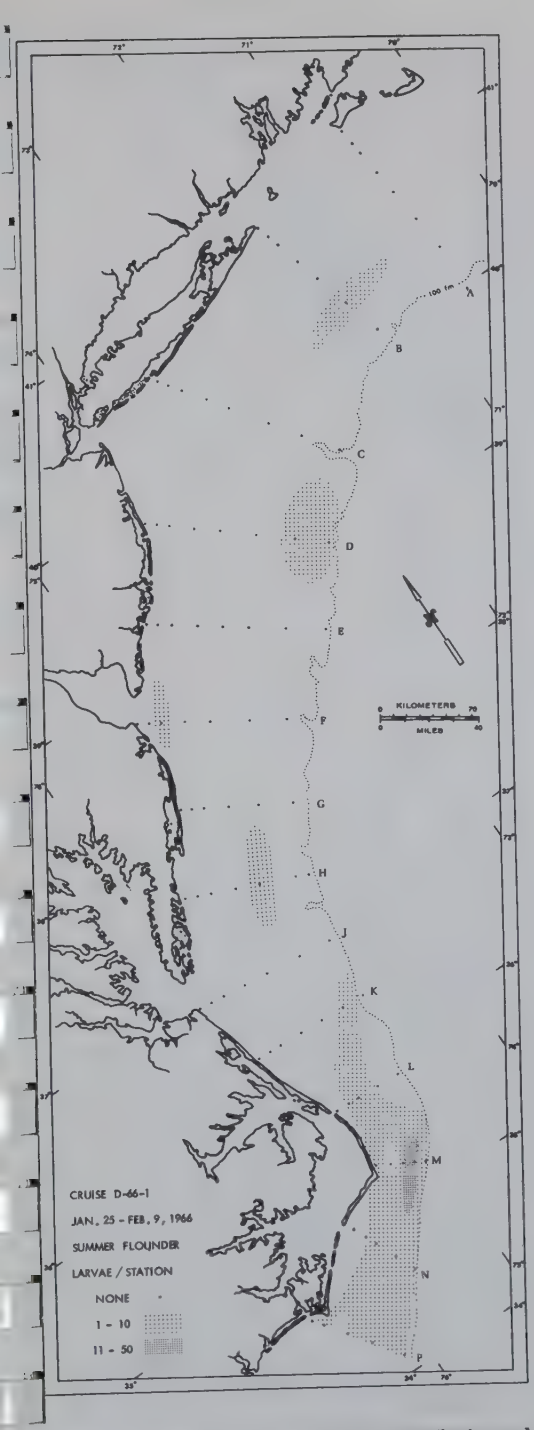


Figure 32.—January to February 1966. Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae.

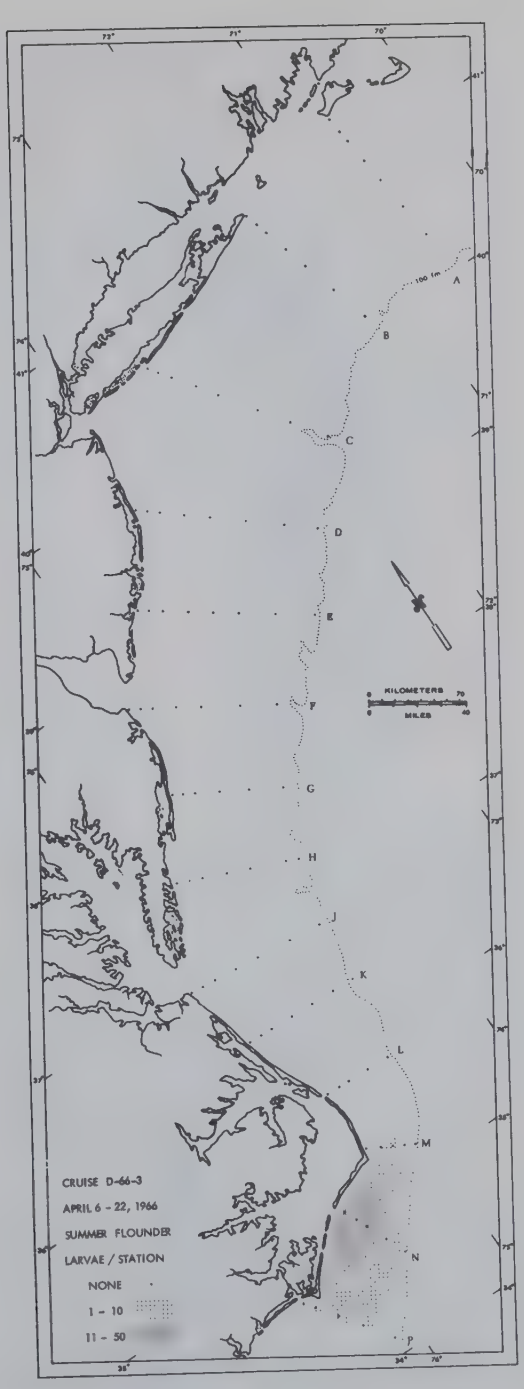


Figure 33.—April 1966. Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae.

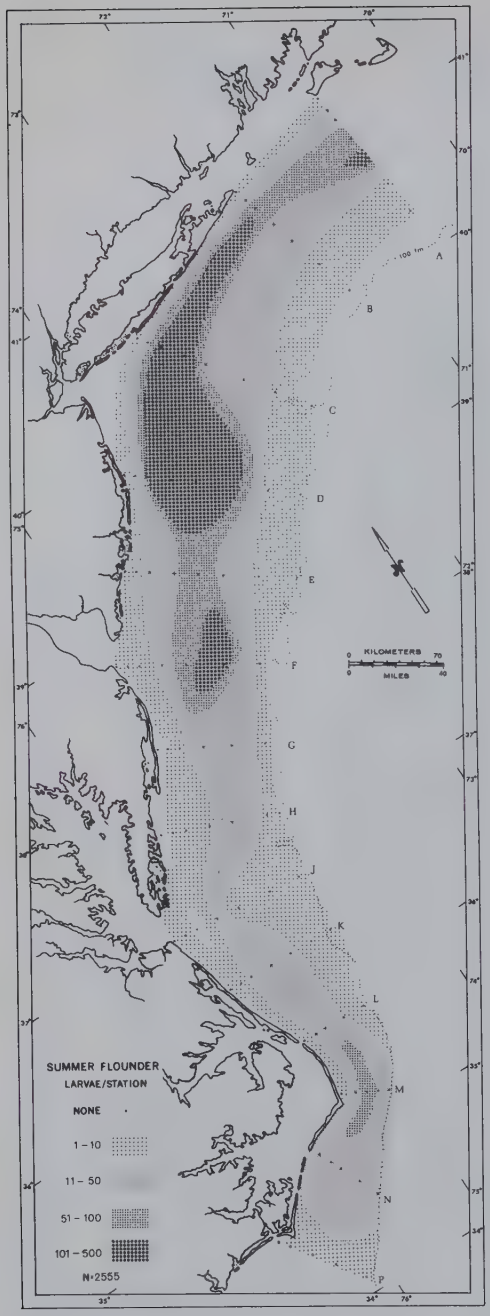


Figure 34.—Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae collected during 1965-66 survey.

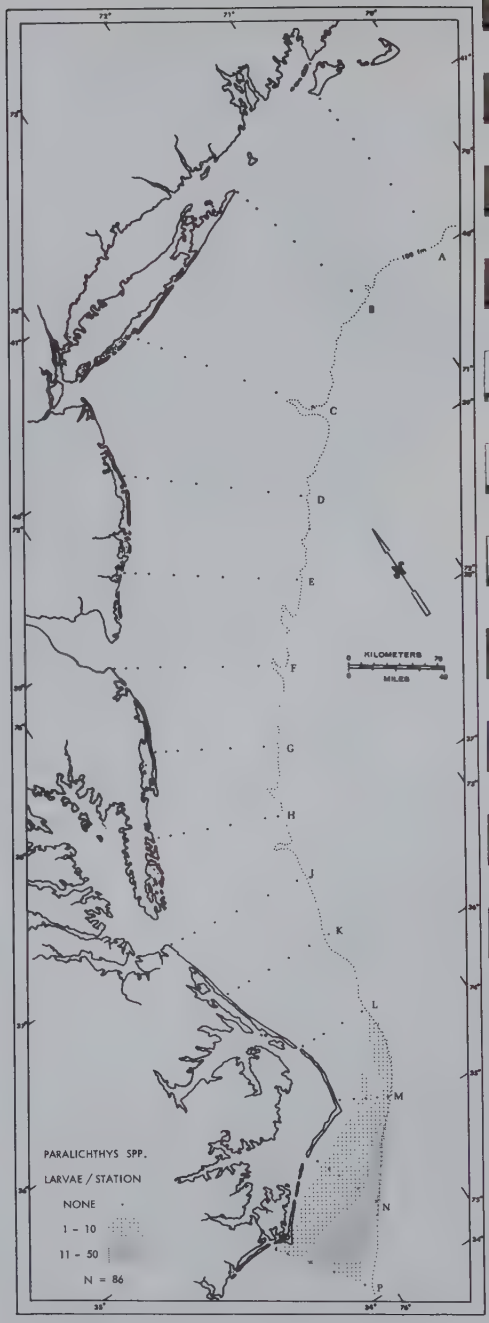


Figure 35.—Distribution and relative abundance of *Paralichthys* spp. larvae collected during 1965-66 survey (excluding *P. dentatus*).

Table 11.--The seasonal distribution of windowpane, Scophthalmus aquosus, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae < 4.1 mm represented recent spawning.

Larval length (mm)	Cruise and date: 66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	66-1 Jan.-Feb.	Total
	Number of larvae									
2.1- 3.0	1	342	43	28	23	353	104	104		998
3.1- 4.0	10	331	25	48	19	798	266	668	1	2,166
4.1- 5.0		141	5	28	8	301	256	983		1,722
5.1- 6.0		41	5	4	2	115	150	376	1	694
6.1- 7.0		8	1	4		52	70	56		191
7.1- 8.0			1	1		5	18	10	1	36
8.1- 9.0			1			3	4	1	1	10
9.1-10.0						1	3	1	1	6
10.1-11.0								1		1
11.1-12.0							3	1		4
12.1-13.0										
13.1-14.0										
14.1-15.0								1		1
Total	11	863	81	113	52	1,628	874	2,202	5	5,829

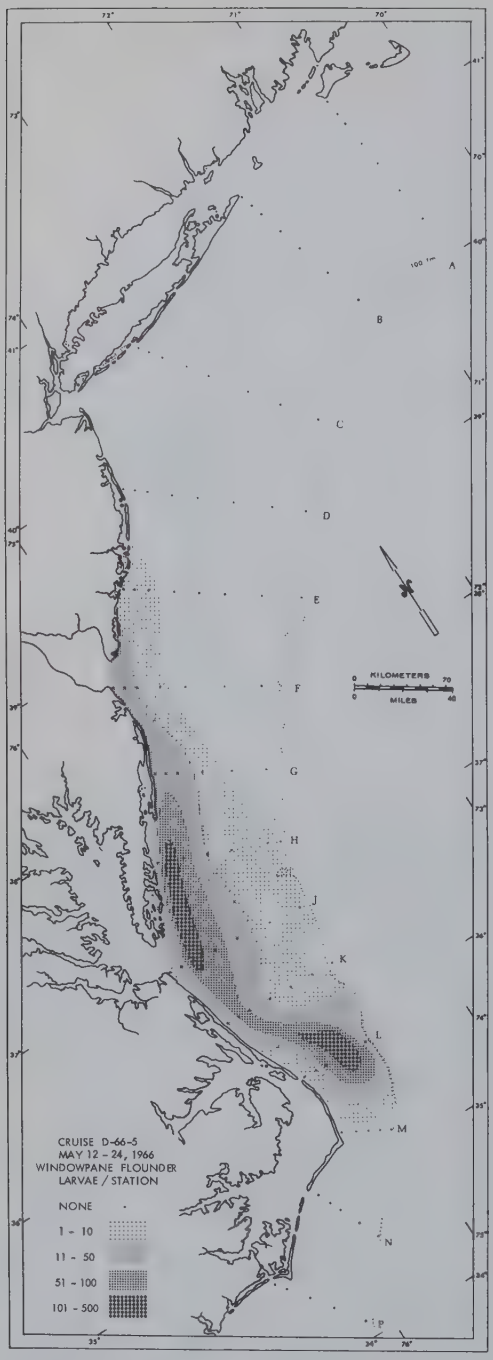
The range of windowpane is somewhat similar to that of spot flounder. Although both are most abundant in the thern half of the bight, they are found at different epths. Gutherz (1967) reported windowpane most bundant in depths <46 m; fourspot flounder in depths >37 m. s is borne out by our larval catches. Windowpane vae were most abundant off New Jersey over depths between 20 and 40 (Fig. 43); fourspot flounder larvae off New ersey in 40 m and off southern New England in 70 m (Fig. 28). oth Wheatland (1956) and Perlmutter (1939) caught dowpane eggs and larvae in Long Island Sound as early s April. We caught larvae off Virginia and North Carolina April, but not as far north as New York until June. Our ults indicate a split spawning season off Virginia and th Carolina, but, contrary to Wheatland's findings in ng Island Sound, not in coastal waters off New York.

Wheatland (1956) doubted that water temperature played ajor role in the interruption of spawning in Long Island nd. Assuming that spawning takes place on the bottom, e see a correlation between water temperatures taken in njunction with her study (Riley 1956) and the hatching peratures of 10.0° to 21.1°C reported by Bigelow and roeder (1953). During Wheatland's survey of the sound, awning began in the spring when the average bottom mperature was 7°C and stopped in the summer when it eeded 20°C. It recommenced in late summer or early soon after the average bottom temperature dropped w 20°C (see Riley 1956). Thus, the upper limits of mperature cited by Bigelow and Schroeder (1953) agree h temperature data collected during the Long Island nd study. Furthermore, our data suggest that spawning is closely tied to temperature. We caught 98% of the recently spawned windowpane larvae, i.e., those <4.1 mm, over bottom temperatures between 6° and 17°C; 70% over temperatures between 8.5° and 13.5°C, a range of 5°. Spawning was interrupted during the summer off Virginia and North Carolina when bottom temperatures exceeded 15°C, and began again in the fall when they dropped to 14°C. Because bottom temperatures off Long Island during our survey were cooler than those recorded by Riley (1956) during Wheatland's work in the sound, we concluded that spawning was not interrupted by excessively warm water off Long Island during our survey, as it was during Wheatland's (1956) study.

Syacium papillosum (Linnaeus), dusky flounder.—Dusky flounder are common in shelf waters off our southeast Atlantic coast, and range into the Gulf of Mexico, the Caribbean Sea, and southward to Brazil. Larval stages were described by Futch and Hoff (1971).

With the exception of one specimen, the distribution of larvae during our survey did not extend north of North Carolina, which conforms with the northernmost range of adults (Gutherz 1967). Throughout the season, we made our biggest catches at stations near the outer edge of the shelf in that area often transected by the meandering Gulf Stream.

The April collections represented the onset of spawning, which probably had occurred south of Cape Lookout. We caught only four larvae: three of them 36 km off Cape Hatteras over a depth of 55 m, the other at our most seaward station off Cape Lookout where the depth was 145 m. Dusky flounder occur at depths from 11 to 384 m, but



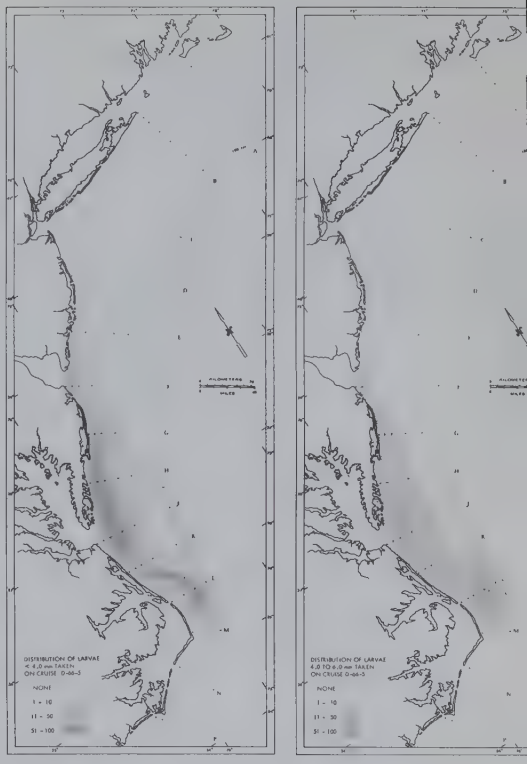


Figure 36.—May 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top < 4.0 mm, 4.0 to 6.0 mm.

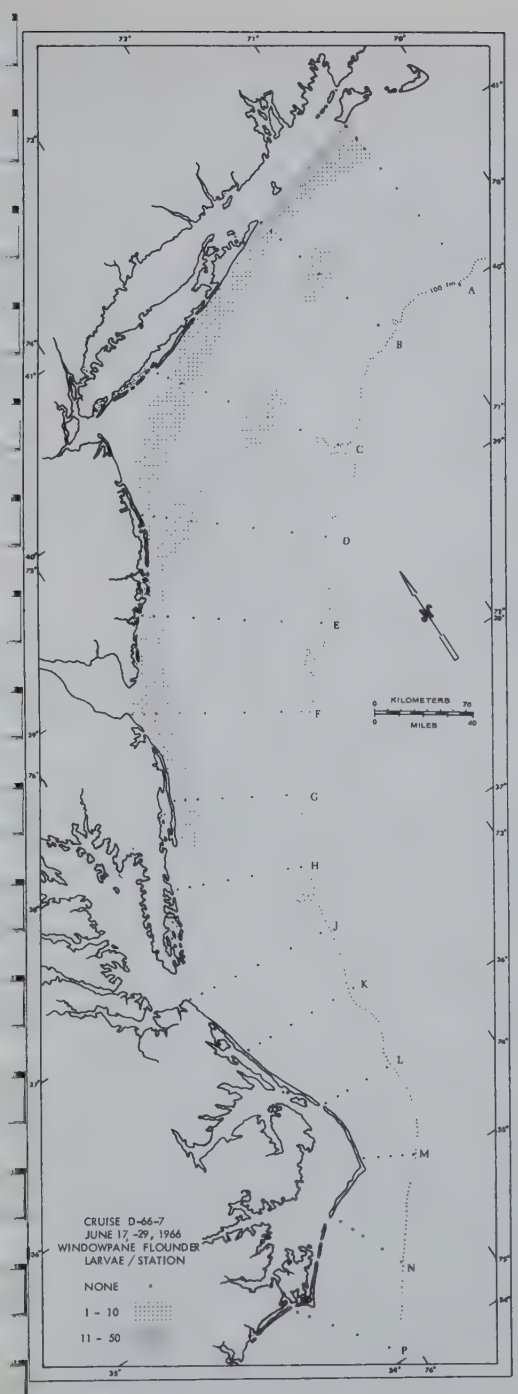


Figure 37.—June 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae.

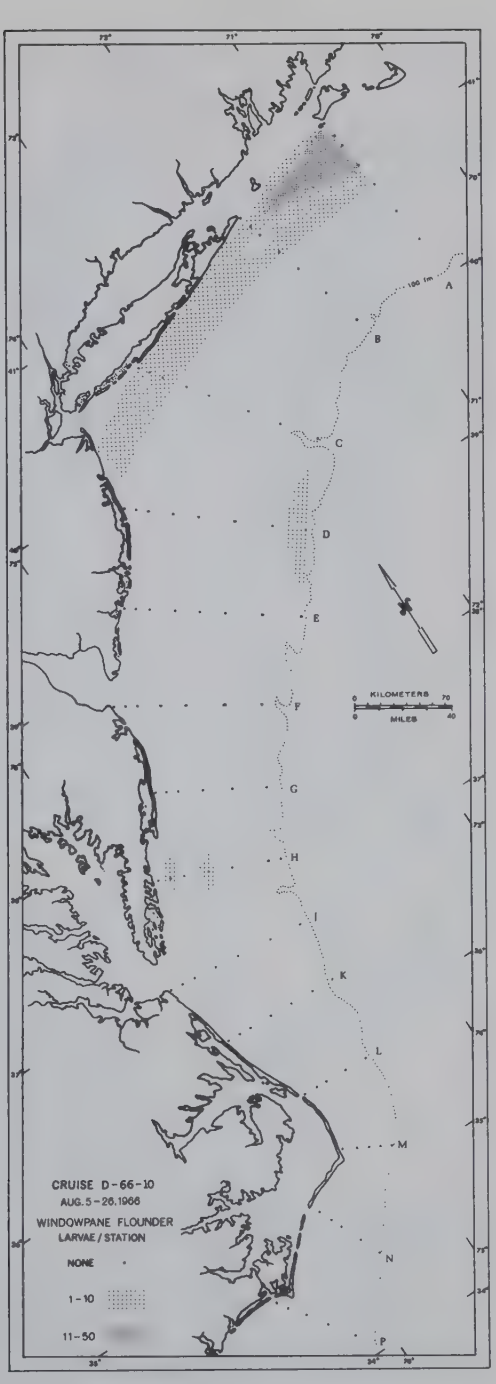


Figure 38.—August 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae.

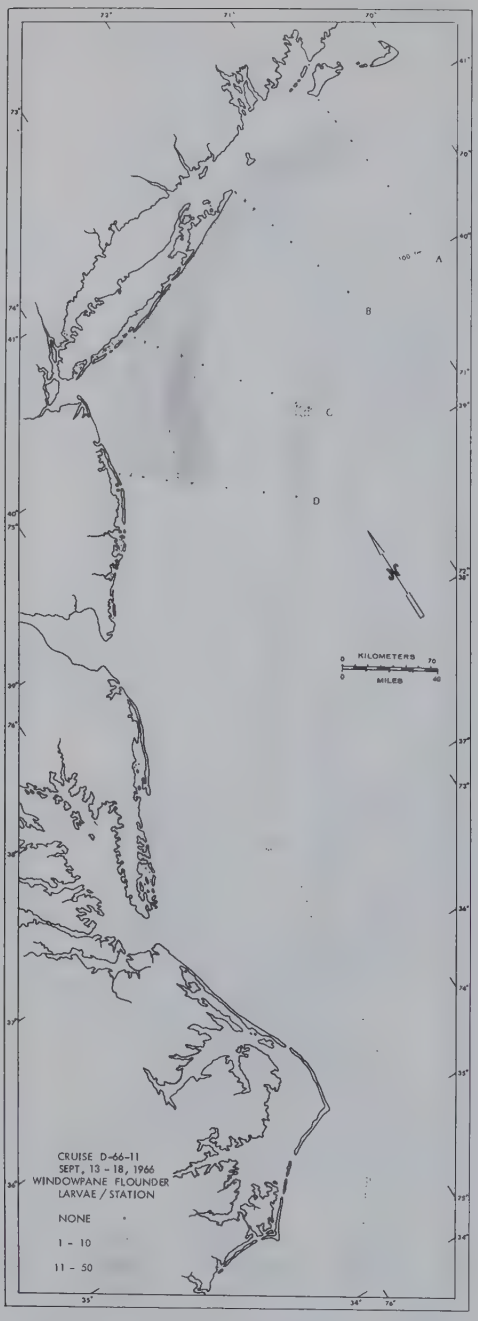


Figure 39.—September 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae.

they are rare at depths >92 m (Bullis and Thompson 1 Fraser (1971) found members of the genus *Syacium* i Straits of Florida at depths from 2 to 140 m, and questi records from depths exceeding 182 m. Surface isoth suggest that both stations where we caught larvae in were within the influence of the Gulf Stream, and, juc from their size and number, we concluded that the la had been transported into the survey area (Table 12).

In May, larvae were confined largely to the southern of the survey area. They were most concentrated bet capes Hatteras and Lookout over a depth of 50 m (Fig. Their size range and numbers indicated that spaw intensity had increased since the April cruise (Table 12) on the previous cruise in April, their distribution se restricted to the Gulf Stream or its edge. The shore limit of their occurrence closely followed the 20°C su isotherm.

The catch in June decreased, but the distrib remained essentially the same as in May (Fig. 45). La were most abundant along the outer edge of the she Cape Hatteras, an area where the depth is probabl great for spawning and the Gulf Stream too swift to p the larvae to remain near the center of spawning. improbable that they represented local spawning.

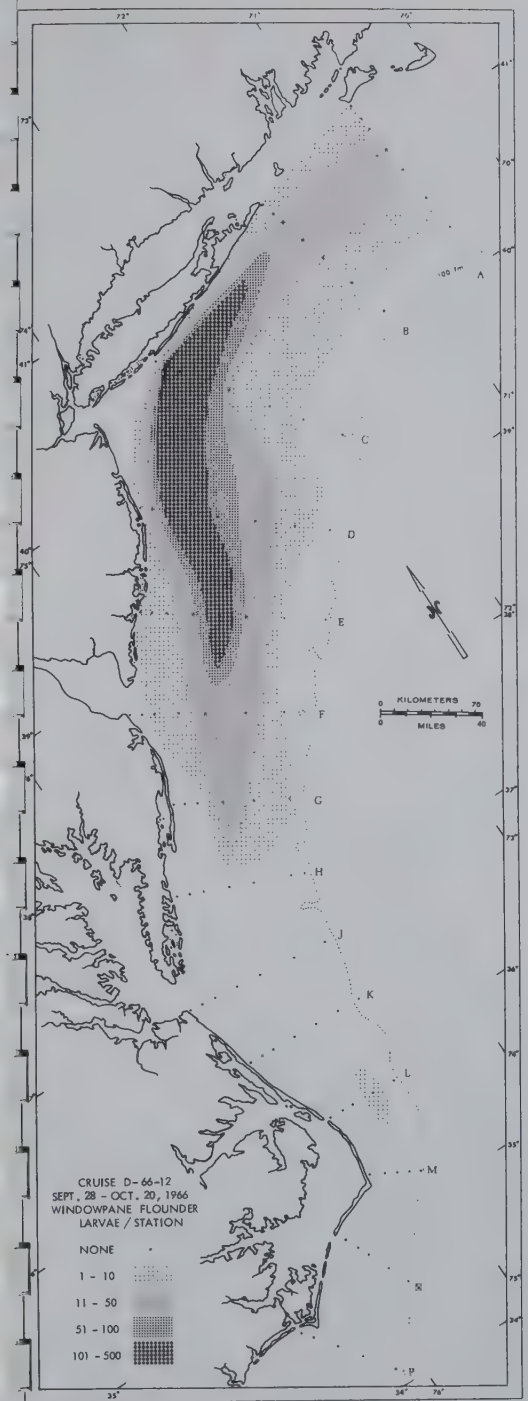
Larvae were most abundant nearshore between Hatteras and Lookout in August. These had probably spawned locally. Although for the first time distribution extended into the survey area north of Hatteras (Fig. 46), the catch decreased slightly, pro because there was little or no influx from the south su had been evident during the earlier cruises.

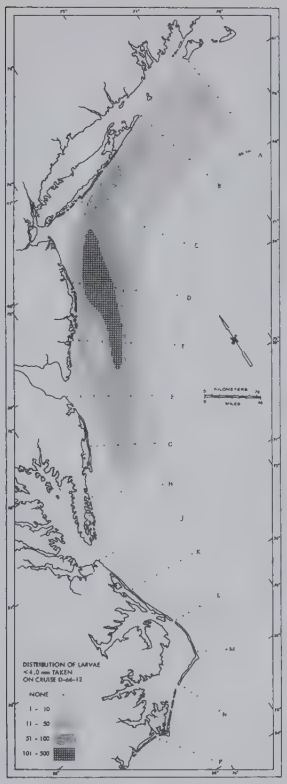
We made our biggest catch in late September (Table The distribution of larvae extended northward to Virg well shoreward of the Gulf Stream. The center of abun occurred at seaward stations between capes Hatteras Lookout, and probably represented spawning that occurred south of the survey area (Fig. 47).

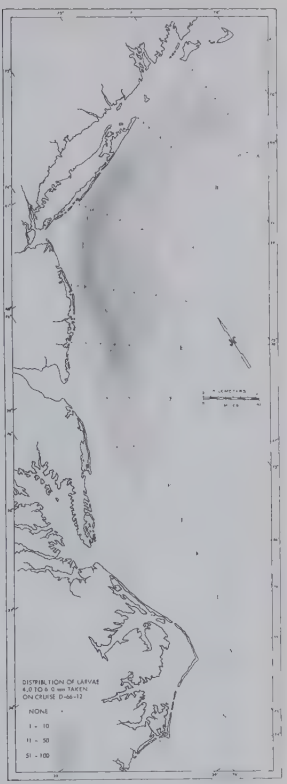
Spawning dropped off sharply by November. We ca fewer larvae than in September, and, with one excep their distribution had receded to that part of the survey between the North Carolina capes. The exception, a s specimen captured off northern Virginia, represente northernmost occurrence of this species in our survey 48).

We caught only six larvae in December (1965), stations near the outer edge of the shelf south of Hatteras. None were taken on the following crui January and February. Judging from the size of the la (Table 12), and their absence on the following cruise presumed that spawning had ended sometime in Nove or, at the latest, early December. Since many of the l we caught had been transported into the survey area b Gulf Stream, it is possible that our catches in Dece reflected the end of spawning along the entire east co

Like most warmwater fishes, dusky flounder ha protracted spawning season. We caught larvae over a period, mostly off the North Carolina coast between Hatteras and Lookout (Fig. 49). The spawning season i area is not very different from that noted for dusky flou in the Gulf of Mexico (Topp and Hoff 1972) and Tampa Fla. (Moe and Martin 1965). They postulated, from go observations, that spawning occurred from Februa November, peaking in May and June. Our collections in that spawning lasts from April to October or Nover Larvae were most abundant from May through Septe and these months probably represent the height







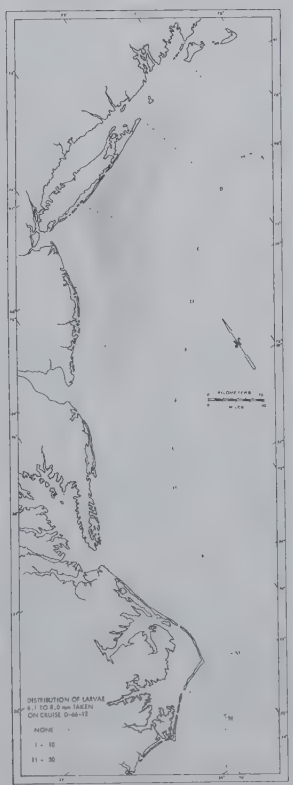
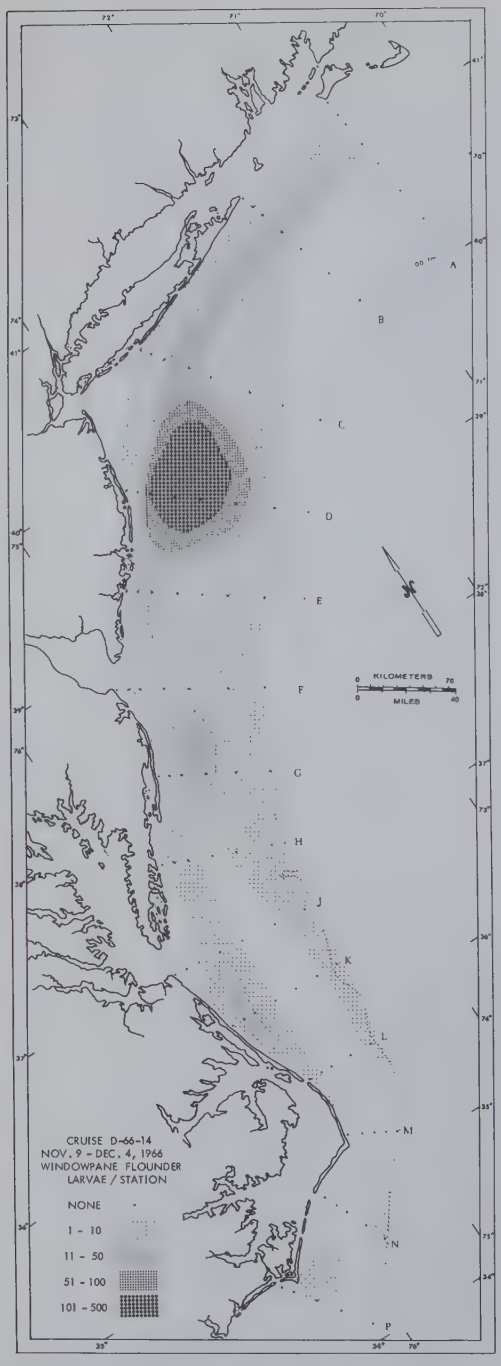
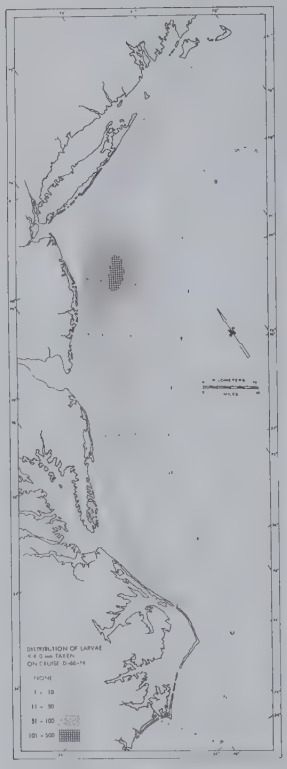


Figure 40.—September to October 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top <4.0 mm, 4.0 to 6.0 mm; bottom 6.1 to 8.0 mm.





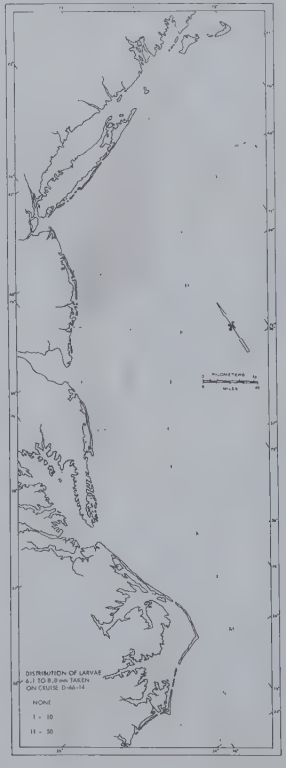
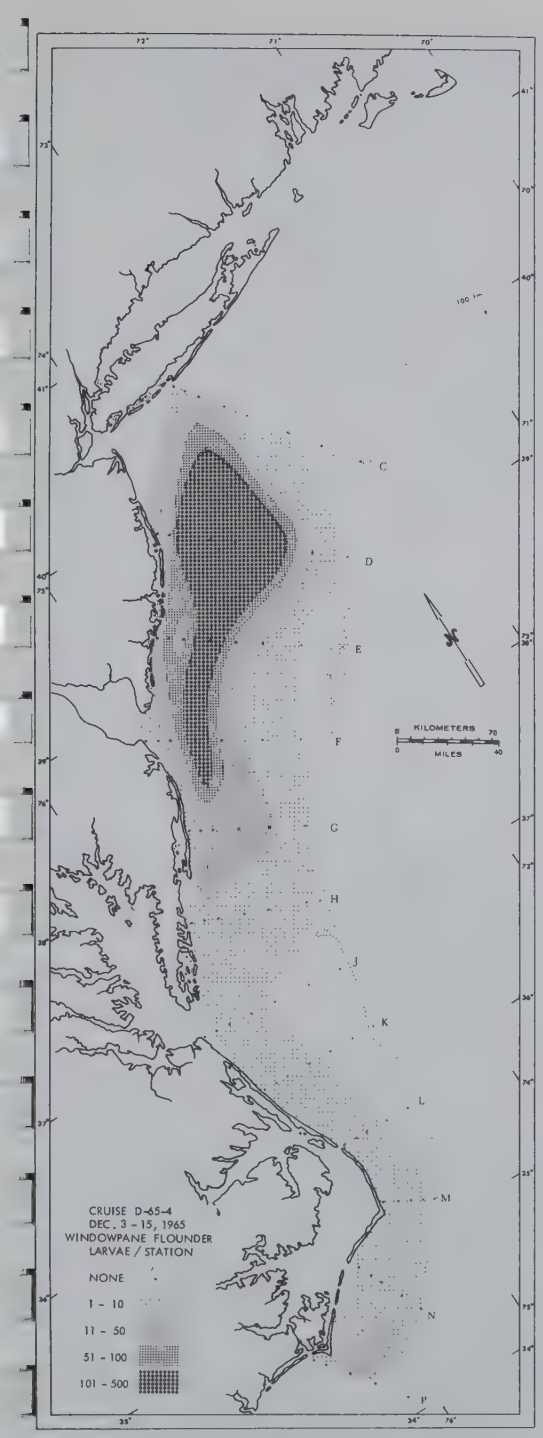
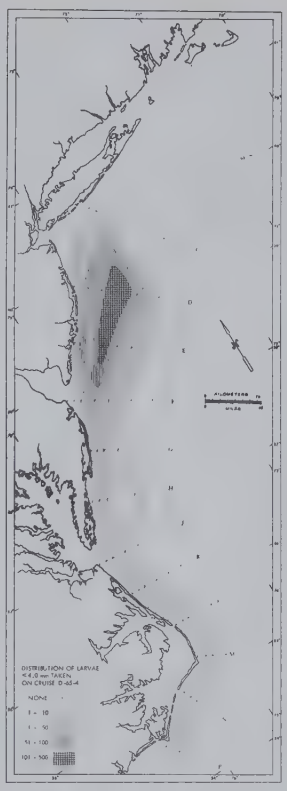
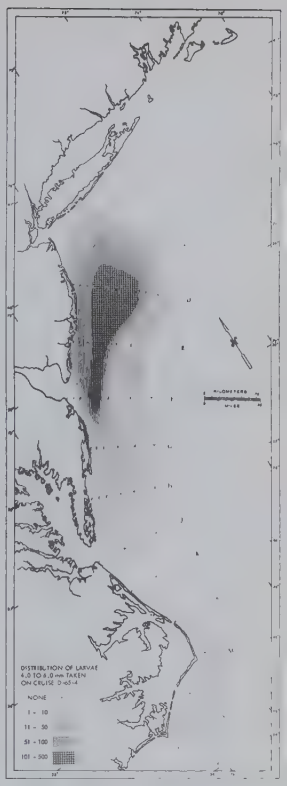


Figure 41.—November to December 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top <4.0 mm, 4.0 to 6.0 mm; bottom 6.1 to 8.0 mm.







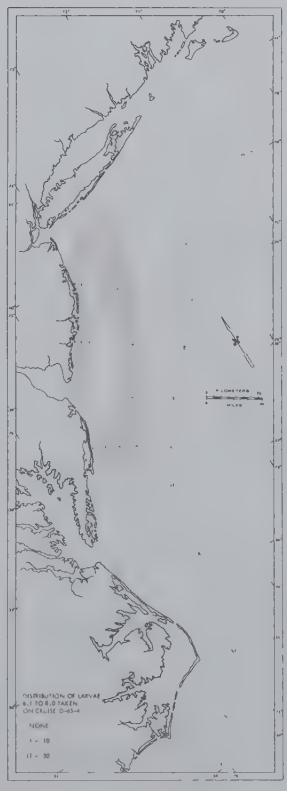


Figure 42.—December 1965. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top <4.0 mm, 4.0 to 6.0 mm; bottom 6.1 to 8.0 mm.

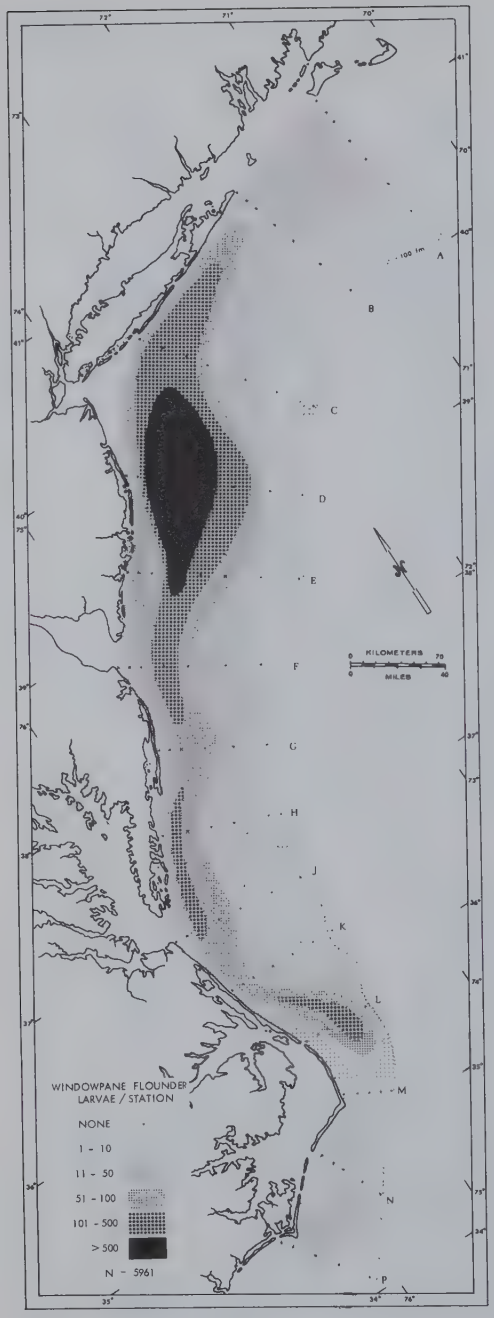


Figure 43.—Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae collected during 1965-66 survey.

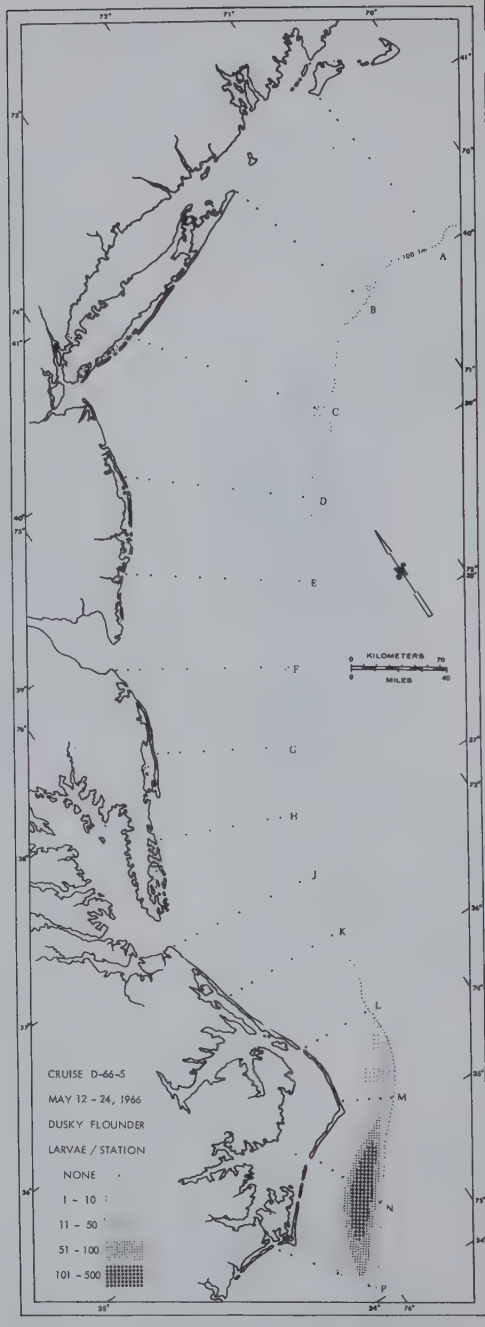


Figure 44.—May 1966. Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae.

Table 12.--The seasonal distribution of dusky flounder, Syacium papillosum, larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date: 66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	Total
	Number of larvae							
1.1- 2.0			2	1				3
2.1- 3.0		42	41	25	70			178
3.1- 4.0	2	161	43	64	78	14	1	363
4.1- 5.0	1	94	105	111	125	14		450
5.1- 6.0		35	42	18	89	13		197
6.1- 7.0	1	13	16	14	58	5	2	109
7.1- 8.0		3	8	9	22	7		49
8.1- 9.0			2	9	12	4	1	28
9.1-10.0			4	2	11	3	1	21
10.1-11.0			2	1	5	1	1	10
11.1-12.0		1	1	2	9	3		16
12.1-13.0					2	2		4
13.1-14.0					3	2		5
Total	4	349	266	256	484	68	6	1,433

pawning season along the entire Atlantic coast.

amily Pleuronectidae—Righteye Flounders

Glyptocephalus cynoglossus (Linnaeus), witch flounder.—
h flounder are deepwater pleuronectids that range from
foundland to North Carolina. They generally occur at
epths between 90 and 330 m. Although more common
orth of Cape Cod than in the bight, adults are moderately
iful off southern New England (Bigelow and Schroeder
), where most of the larvae were collected during our
urvey. Bigelow and Schroeder (1953) found no evidence of
easonal movements, but Powles and Kohler (1970) reported
adults tend to inhabit shallower depths in summer, the
ning season, than in winter in the Gulf of St. Lawrence.
pawning begins in the Gulf of Maine in the spring and
ontinues through the summer months, reaching its peak in
and August (Bigelow and Schroeder 1953). Larvae
described by Bigelow and Schroeder (1953) and Colton
nd Marak (1969).

We caught larvae from April to October. In the area
h we surveyed, spawning evidently peaked during May
June, earlier than in more northern waters. It
pparently ended in July, since we caught no larvae in
ugust. Although larvae of this species were only
rately abundant in our collections, they were numerous
gh to indicate the duration and peak of the spawning
eason at the southern end of the witch flounder's range.

When we first caught larvae in April, they were scattered
een North Carolina and Long Island over depths of 10
m (Fig. 50). Although some of the larvae were taken in shallower water than that normally frequented by adults, we assumed from their small size and the narrow size range that all were recently hatched. Colton and Marak (1969) reported that larvae were 3.5 to 5.6 mm at hatching, with an average length of 4.8 mm. Most of the witch flounder larvae we caught in April were <6 mm (Table 13).

Spawning advanced both northward and seaward in May. While the distribution of larvae extended the entire length of the bight, the center of abundance was located off Long Island over 75 m of water (Fig. 51). The bottom temperature at the center of abundance was 5°C. We caught a greater size range of larvae than on the previous cruise, and the number of small larvae indicated a marked increase in spawning activity (Table 13). A significant north-to-south gradation was evident in the size of larvae. Those captured off Long Island and southern New England were small and recently hatched ($\bar{x}$ = 5.6 mm). They were progressively larger from New Jersey ($\bar{x}$ = 6.5 mm) to North Carolina ($\bar{x}$ = 11.6 mm). This size difference might reflect growth during transport southward along the shelf or, alternatively, earlier spawning off North Carolina than off southern New England.

The distribution of larvae in June was continuous from southern New England to Maryland. Further south, larvae were scattered. The center of abundance occurred off eastern Long Island and southern New England, east of that in May, over 80 to 90 m of water (Fig. 52). Although the areal extent of larval distribution was less than during the previous cruise, the catch was slightly greater (Table 13). The north-to-south progression in size of larvae was again evident. Those caught off southern New England and eastern Long Island had a mean length of 6.3 mm; off

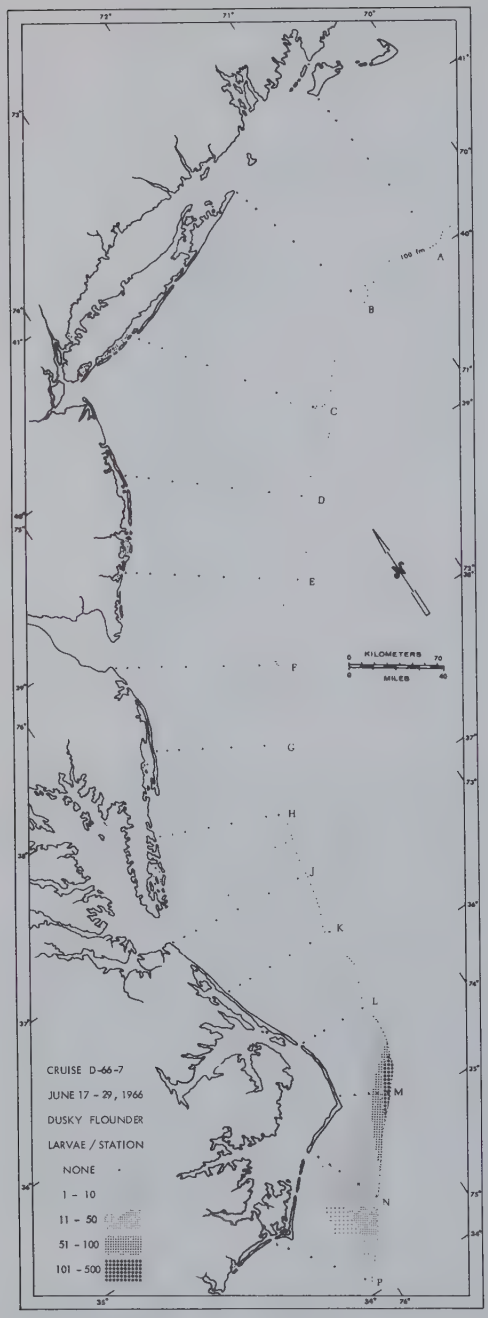


Figure 45.—June 1966. Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae.

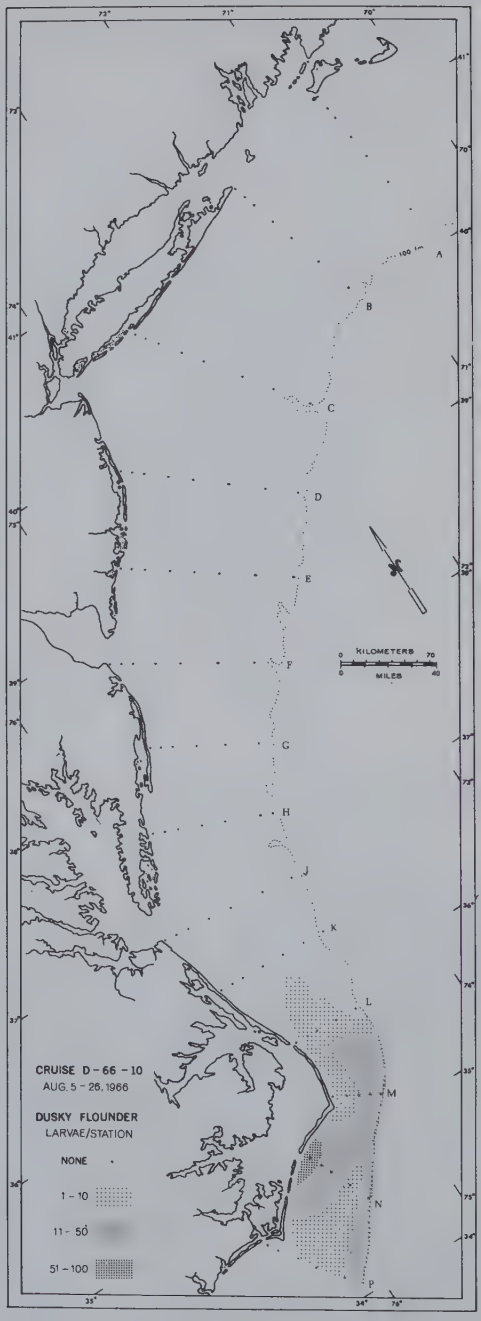


Figure 46.—August 1966. Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae.

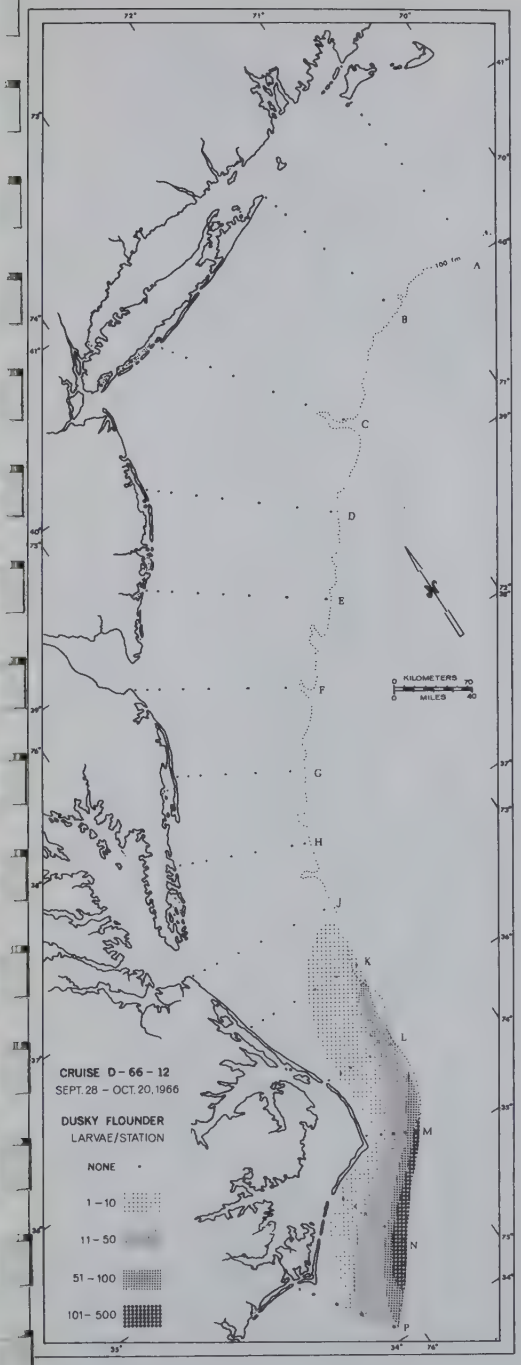


Figure 47.—September to October 1966. Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae.

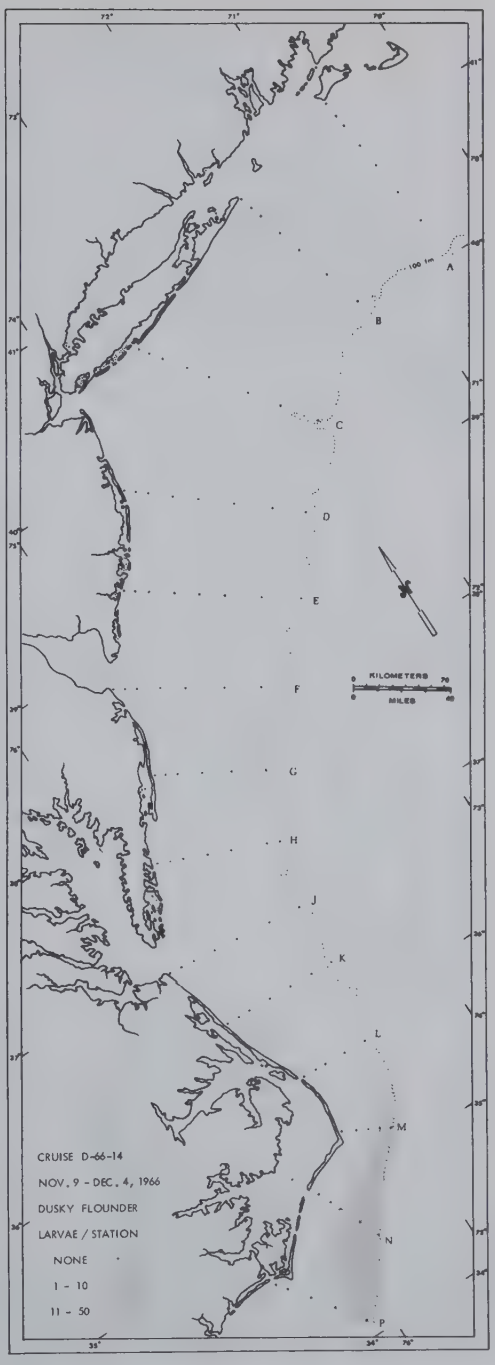


Figure 48.—November to December 1966. Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae.

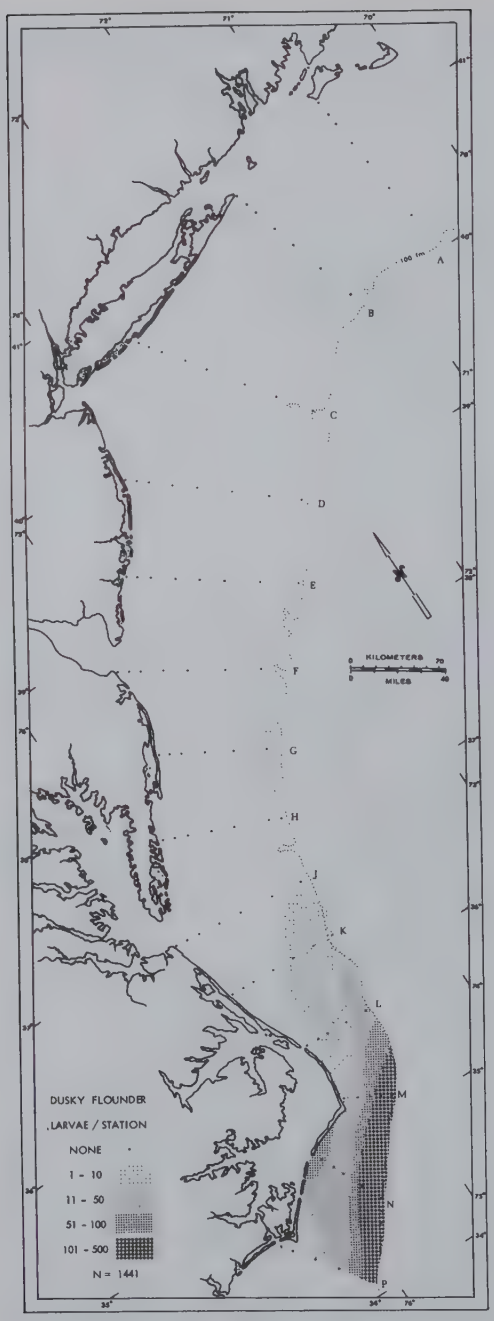


Figure 49.—Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae collected during 1965-66 survey.

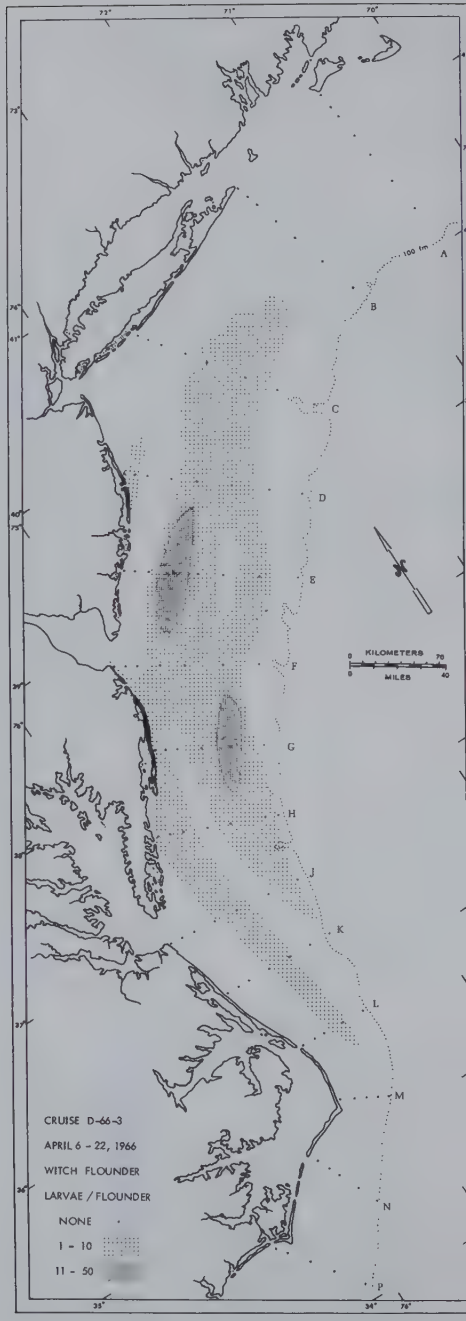


Figure 50.—April 1966. Distribution and relative abunda of witch flounder, *Glyptocephalus cynoglossus*, larvae.

Table 13.--The seasonal distribution of witch flounder, Glyptocephalus cynoglossus, larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date 66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	Total
	Number of larvae						
3.1- 4.0		2	41	1			44
4.1- 5.0	17	106	79	4			206
5.1- 6.0	31	212	77	7	1		328
6.1- 7.0	6	74	67	5			152
7.1- 8.0	2	26	81	5			114
8.1- 9.0		11	65	6	1		83
9.1-10.0		8	27	7			42
10.1-11.0		3	21	12			36
11.1-12.0		5	6	9			20
12.1-13.0		4	5	11			20
13.1-14.0		3	4	4			11
14.1-15.0		5	5	7			17
15.1-16.0		1	3	5	1		10
16.1-17.0			2	4			6
17.1-18.0		2	5	4			11
18.1-19.0				2	2		4
19.1-20.0			3	2	1		6
20.1-21.0			1	4		1	6
21.1-22.0							
22.1-23.0		1		1		1	3
23.1-24.0			1	2			3
24.1-25.0			1	4	1		6
25.1-26.0				2			2
26.1-27.0			1	1			2
27.1-28.0				3			3
28.1-43.0			3	4	1	2	10
Total	56	463	498	116	8	4	1,145

rn Long Island to Virginia 10.7 mm; and off North Carolina 28.0 mm.

Spawning had nearly ended by August. Although the dis- on of larvae was continuous from New England to Carolina, we caught far fewer than during the previous two cruises, and larvae <6 mm were taken at only wo stations (Fig. 53). Compared to the previous cruise, throughout the survey area increased in average size. caught in the northern corner of the survey area had mean length of 10.1 mm, and from Long Island to Virginia 8.0 mm. The lone specimen caught off North Carolina was m long.

ses in September and October yielded a total of 12 larvae, which were scattered from southern New England to the outer banks of North Carolina. Only two were <15 mm, which is further evidence that spawning in the bight had run its course by August, a month when spawning is at its peak north of Cape Cod.

As with other spring-spawning flatfishes, the spawning season of witch flounder begins in the southern part of the range and subsequently progresses northward. Although we first caught larvae off Virginia and North Carolina, the most important spawning grounds in the bight were off Long Island and southern New England, the part of the survey area where other pleuronectid larvae (Fig. 54) were most abundant during our survey.

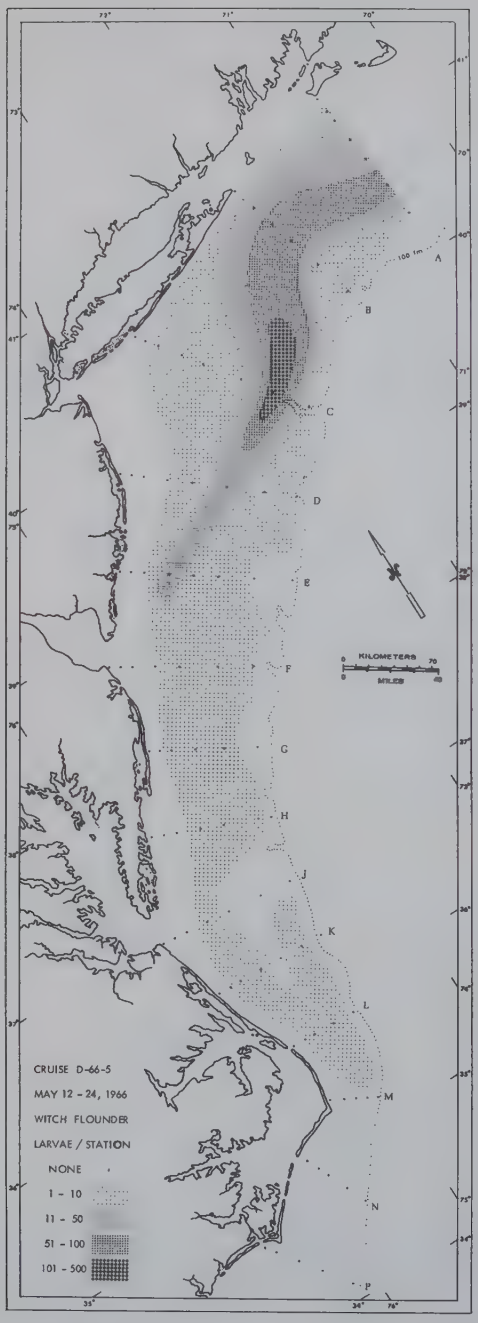


Figure 51.—May 1966. Distribution and relative abundance of witch flounder, *Glyptocephalus cynoglossus*, larvae.

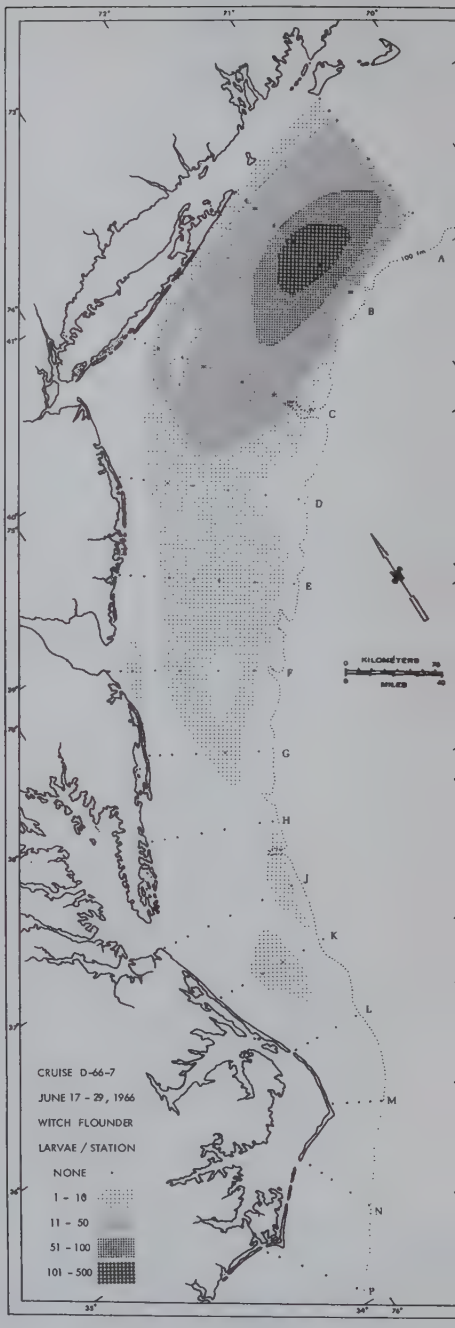


Figure 52.—June 1966. Distribution and relative abundan of witch flounder, *Glyptocephalus cynoglossus*, larvae.

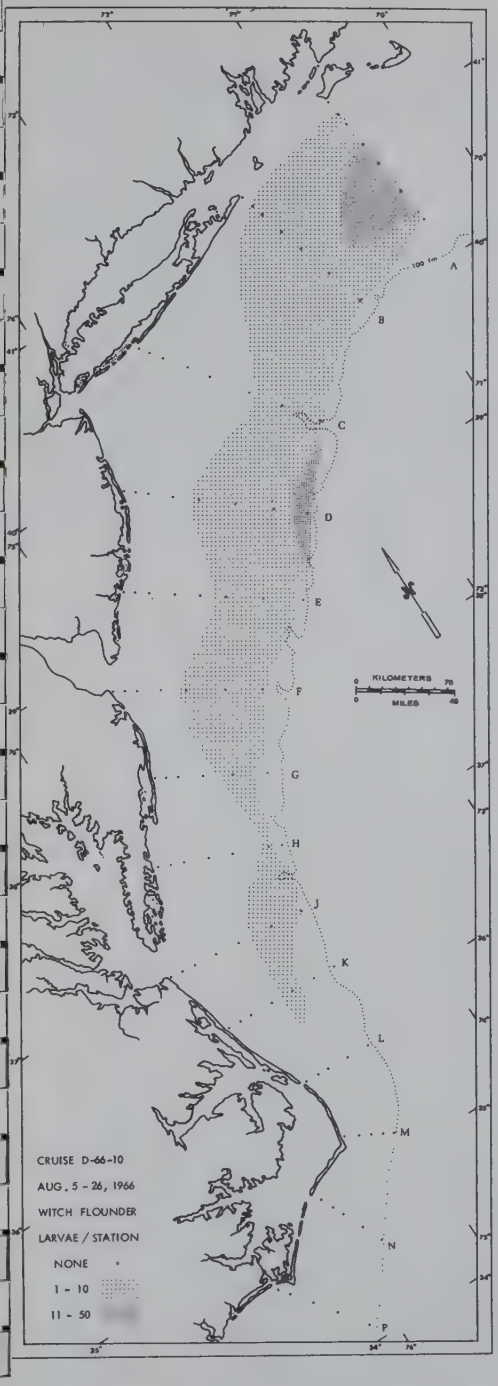


Figure 53.—August 1966. Distribution and relative abundance of witch flounder, *Glyptocephalus cynoglossus*, larvae.

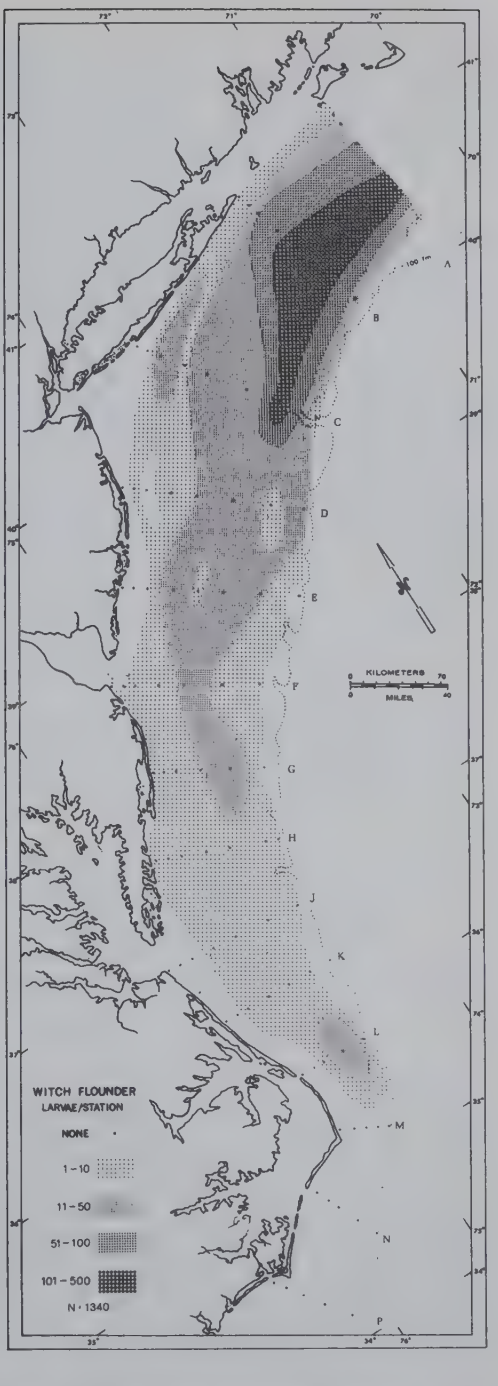


Figure 54.—Distribution and relative abundance of witch flounder, *Glyptocephalus cynoglossus*, larvae collected during 1965-66 survey.

Hippoglossus hippoglossus (Linnaeus), Atlantic halibut.—Atlantic halibut inhabit boreal and subarctic waters on both sides of the Atlantic Ocean. Although they have been caught as far south as Virginia in the western Atlantic, those taken south and west of Nantucket Shoals and the southern edge of Georges Bank are considered stragglers (Bigelow and Schroeder 1953). Larvae were described by Schmidt (1904).

Unlike most other pleuronectids, halibut have an extended spawning season. Ripe females have been reported from April through early September from Georges Bank to the Grand Banks. In the eastern Atlantic, most spawning takes place in the spring, though ripe adults have been captured as early as January (Bigelow and Schroeder 1953).

We caught only one larva, a 21.2 mm specimen, during the survey. It was taken near the Hudson Canyon at station C-7 on 14 May (Fig. 1). It probably originated somewhere on Georges Bank and was subsequently transported by coastal circulation into the bight.

Hippoglossoides platessoides (Fabricius), American plaice.—American plaice are found on both sides of the Atlantic Ocean. This arctic-boreal pleuronectid is most common from Newfoundland to Cape Cod in the western Atlantic. Martha's Vineyard marks the southern limit of its range. Spawning begins in March, peaks in May, and ends by mid-June north of Cape Cod (Bigelow and Schroeder 1953). Larvae were described by Bigelow and Schroeder (1953) and Colton and Marak (1969).

Our survey area overlapped the distribution of plaice in the vicinity of Cape Cod. Although we caught larvae during only one cruise, their occurrence in our samples conforms with both the spawning season and the southern limit of adult distribution reported by Bigelow and Schroeder (1953).

We caught 80 larvae in May at the northern end of the survey area. There were no concentrations that would suggest nearby spawning; instead, the larvae were scattered mostly south of Martha's Vineyard (Fig. 55). Their size range (5.1 to 16.4 mm), infrequent occurrence, sparseness, and the general circulation pattern off southern New England all suggest that these larvae had been spawned along the southern edge of Georges Bank and subsequently carried into the bight by currents.

Limanda ferruginea (Storer), yellowtail flounder.—Yellowtail flounder, the most economically important flatfish in the western North Atlantic, range from the Gulf of St. Lawrence to Chesapeake Bay, but they are most abundant from the western Gulf of Maine to southern New England. Spawning north of Cape Cod begins in March, peaks in May, and continues through the summer (Bigelow and Schroeder 1953). Although the center of abundance of adults lies north and east of the bight, yellowtail flounder larvae were the most abundant flatfish larvae in our collections. Larvae were described by Perlmutter (1939), Bigelow and Schroeder (1953), and Colton and Marak (1969).

Larvae first appeared in our April samples, and we assume that spawning began sometime between then and the end of the January-February cruise, probably in March. Their distribution extended from North Carolina to the eastern tip of Long Island. The greatest concentration of larvae was located 55 km off southern New Jersey over depths of 30 to 40 m, where the bottom temperature was 6.6°C. The majority of the larvae in the center of abundance

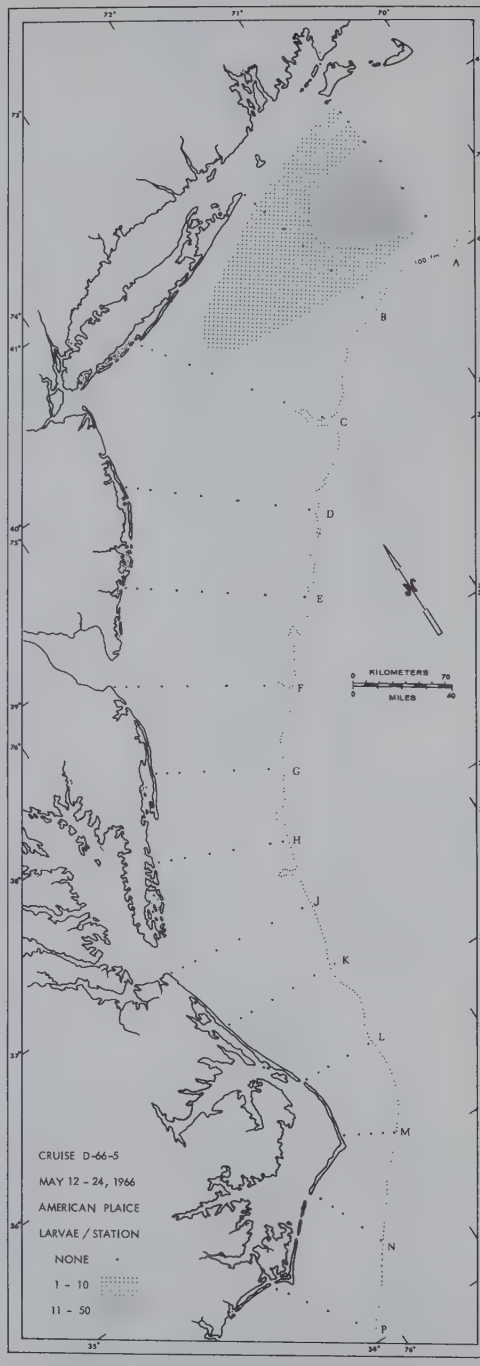


Figure 55.—May 1966. Distribution and relative abundance of American plaice, *Hippoglossoides platessoides*, larvae.

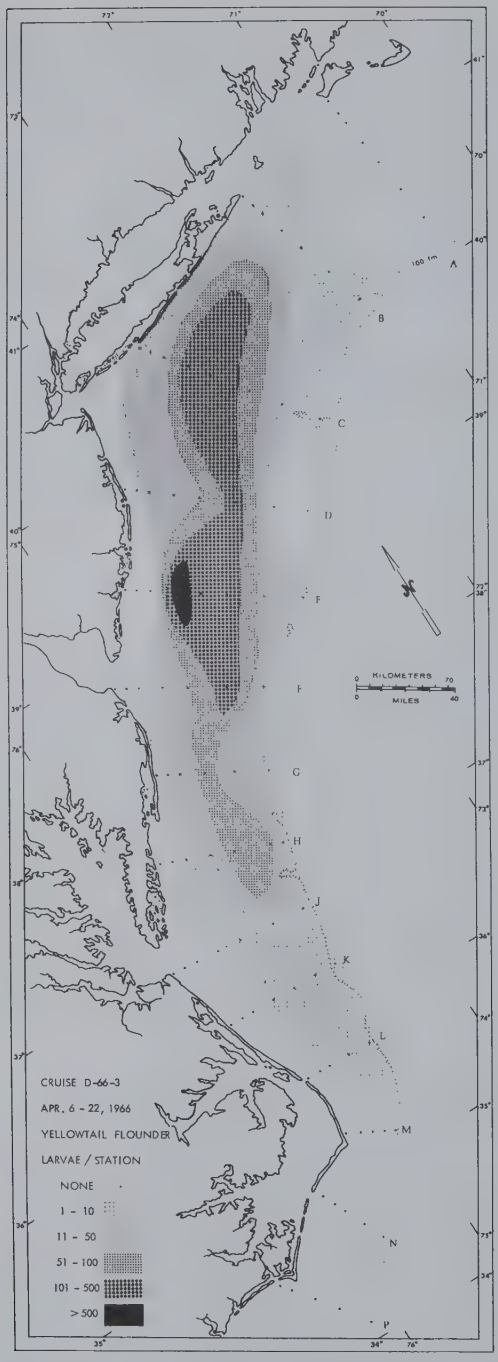
<4 mm, and probably had been spawned nearby. ntermediate-sized larvae (4.1 to 8.0 mm) were most bundant in the same area, with lesser concentrations found e Delmarva Peninsula and off northern New Jersey ong Island. The presence of larvae >4.0 mm both orth and south of the center of abundance suggests that pawning was not restricted to waters off the coast of ern New Jersey, but had occurred before the April from North Carolina to New York. Specimens of 8 to 2 mm were taken at just three stations, two off Virginia nd one off North Carolina (Fig. 56).

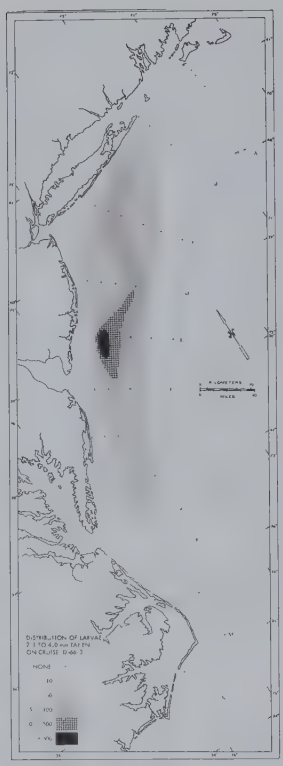
caught larvae from Cape Hatteras to southern New nd in May, finding two concentrations both larger than hat found in April. The smaller of the two was located 110 m off Maryland and Delaware. The other covered the small r of abundance found off southern New Jersey in April, xtended north and east to a point 125 km southwest of Iontauk Point. Based on the distribution of larvae <4 mm, ecent spawning had occurred at depths of 30 to 80 m along a w band extending from Virginia to New Jersey, and eastern Long Island to southern New England at epths of 55 to 75 m. Bottom temperatures off New Jersey and Virginia ranged from 6.8° to 8.7°C and off southern New England from 4.1° to 4.9°C. Intermediate-sized larvae, which made up the bulk of the catch, were abundant from Maryland to southern New England, chiefly off Delaware Bay and off the New Jersey coast. Large larvae, more numerous in May than in April, were caught in two separate areas: one off North Carolina and Virginia and the other from Delaware Bay to Long Island. Specimens >12 mm were caught only off North Carolina and Virginia (Fig. 57).

In June, the areal extent of larval distribution resembled that of May, but the major concentration had shifted to the north and east of the center of abundance of the previous cruise, and was now positioned off southern New England. The distribution of small larvae indicated that recent spawning occurred only off southern New England at depths of 45 to 75 m and bottom temperatures between 4.5° and 8.1°C. As in May, intermediate-sized larvae predominated, but their center of abundance, like that of the smaller group, had moved to the northeastern end of the bight. We caught large larvae from Long Island to North Carolina. They were most abundant midway out on the shelf south of Long Island and east of New Jersey. Unlike the two groups of

Table 14.--The seasonal distribution of yellowtail flounder, Limanda ferruginea, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae < 4.1 mm represented recent spawning.

Larval length (mm)	Cruise and date 66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	Total
	Number of larvae					
2.1- 3.0	66	139	98			303
3.1- 4.0	1,011	1,243	1,049	1		3,304
4.1- 5.0	797	2,841	2,376	2		6,016
5.1- 6.0	203	3,053	2,341	12		5,609
6.1- 7.0	65	1,393	1,179	22	1	2,660
7.1- 8.0	17	635	583	31		1,266
8.1- 9.0	8	374	357	30	1	770
9.1-10.0		142	351	23		516
10.1-11.0		48	358	23		429
11.1-12.0	1	12	340	13		366
12.1-13.0		8	381	15	1	405
13.1-14.0		4	399	10		413
14.1-15.0			322	13	1	336
15.1-16.0			209	1		210
16.1-17.0			97	1		98
17.1-18.0			71			71
18.1-19.0			18			18
19.1-20.0			14			14
20.1-21.0			1			1
Total	2,168	9,892	10,544	197	4	22,805





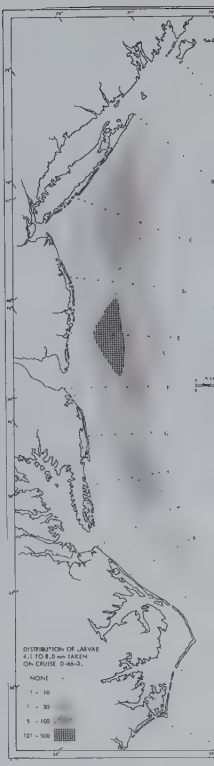


Figure 56.—April 1966. Distribution and relative abundance of yellowtail flounder, *Limanda ferruginea*, larvae (left) and (right) their distribution and relative abundance by size groups. Top 2.1 to 4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm.

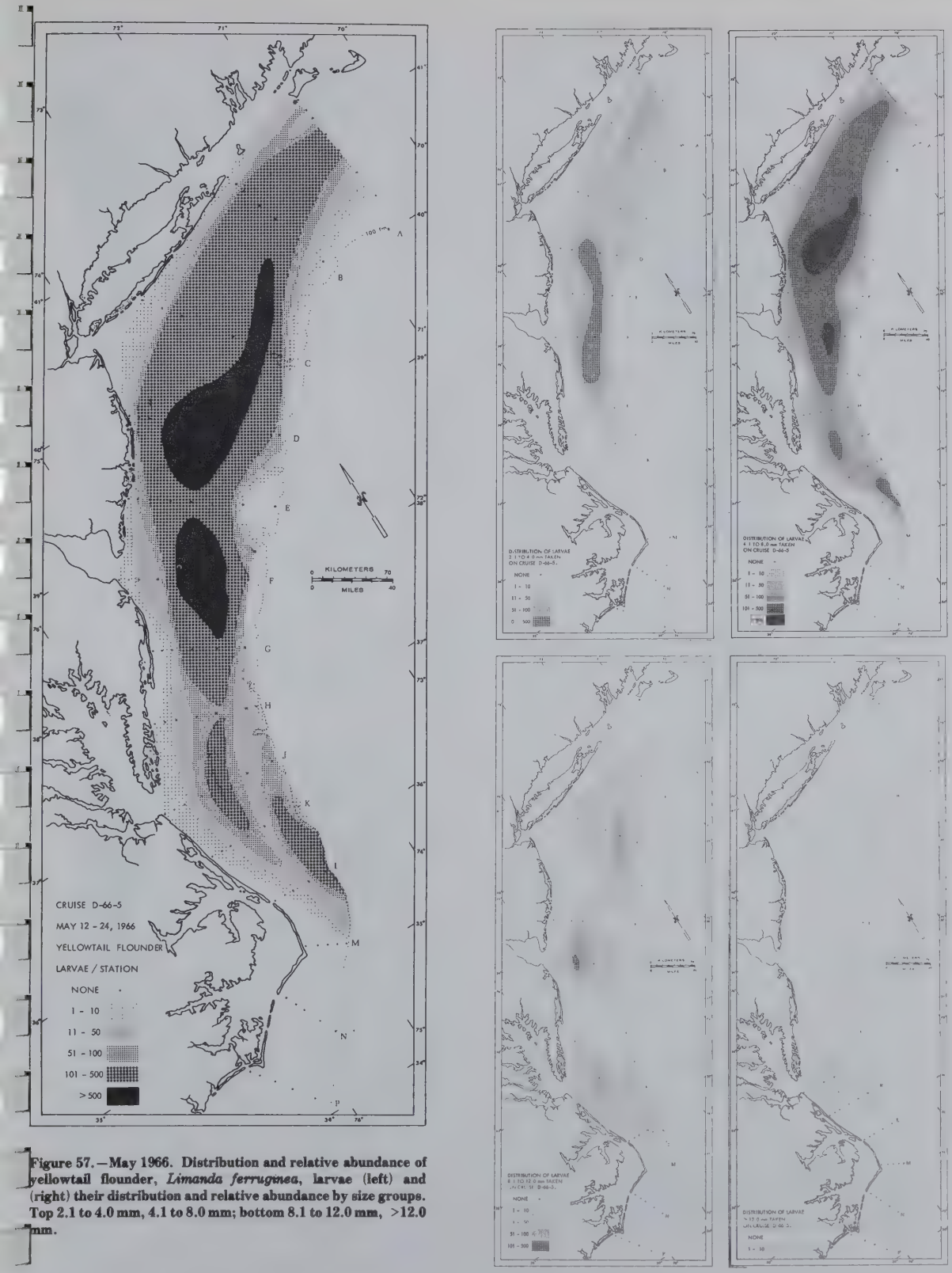
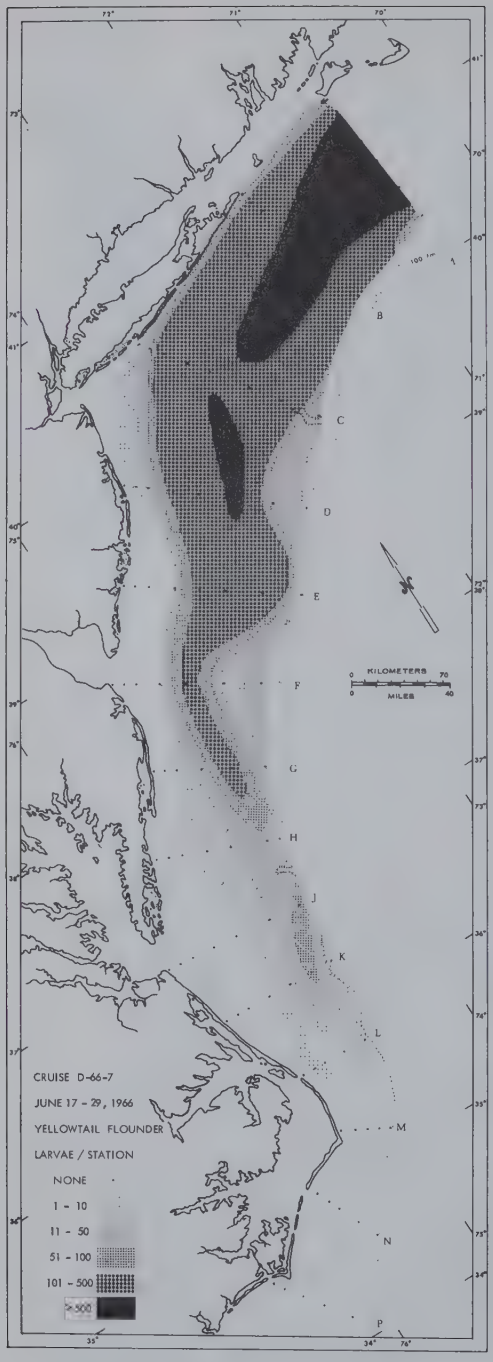


Figure 57.—May 1966. Distribution and relative abundance of yellowtail flounder, *Limanda ferruginea*, larvae (left) and (right) their distribution and relative abundance by size groups. Top 2.1 to 4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm, >12.0 mm.



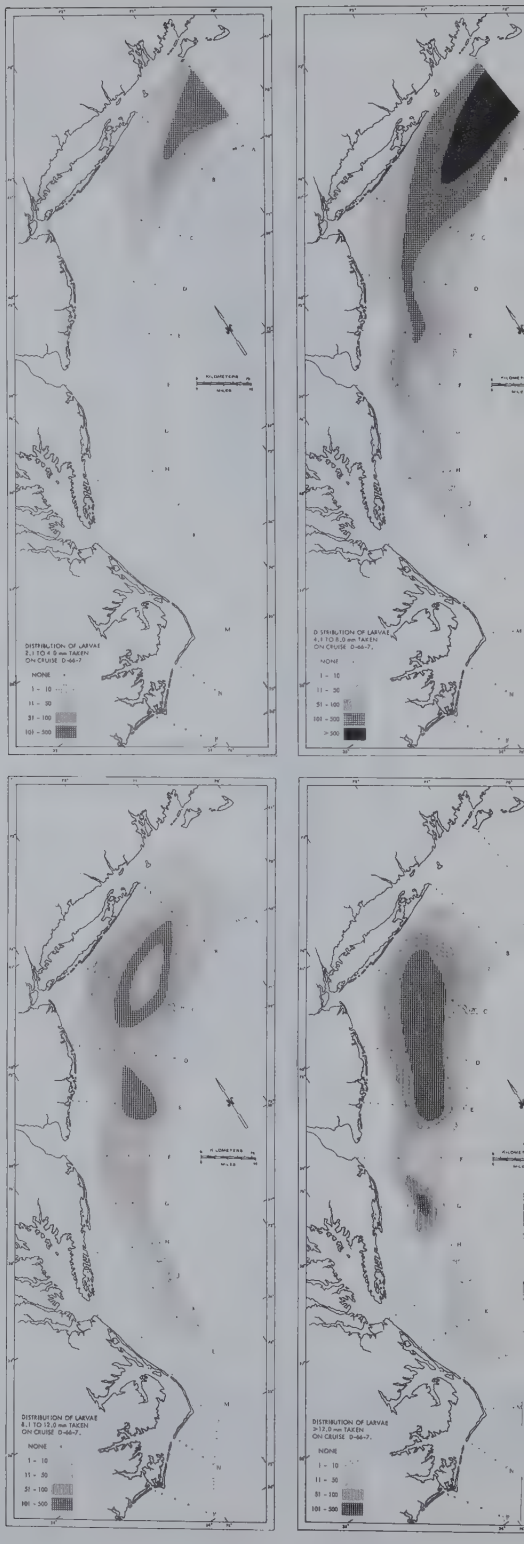


Figure 58.—June 1966. Distribution and relative abundance of yellowtail flounder, *Limanda ferruginea*, larvae (left) and (right) their distribution and relative abundance by size groups. Top 2.1 to 4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm, >12.0 mm.

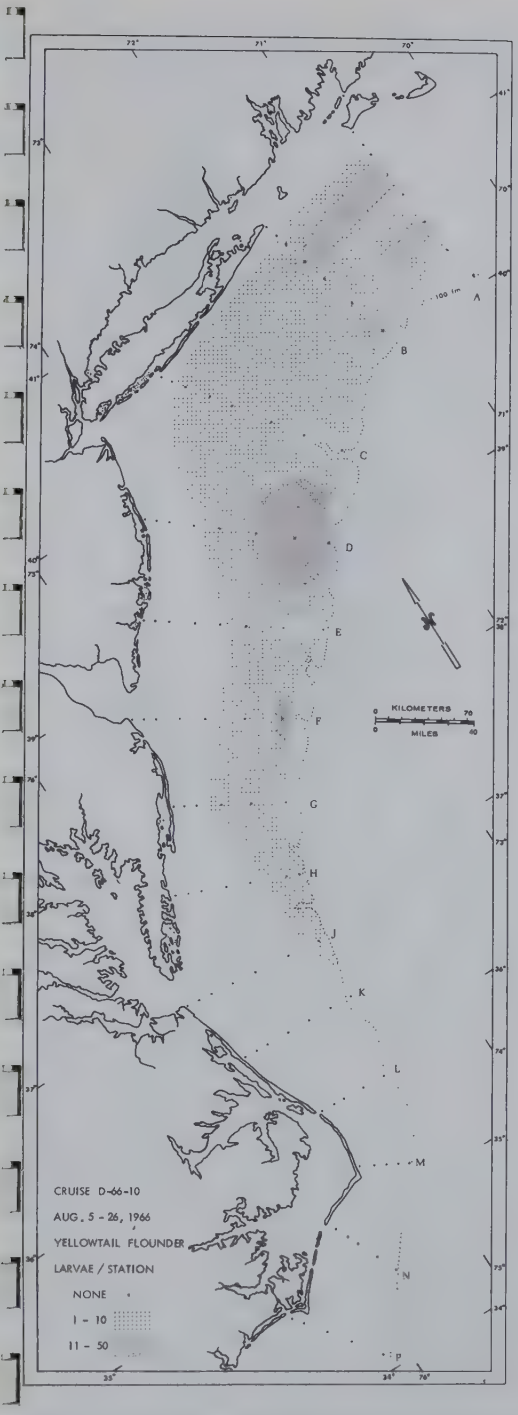


Figure 59.—August 1966. Distribution and relative abundance of yellowtail flounder, *Limanda ferruginea*, larvae.

smaller-sized larvae, no large ones occurred off southern New England. Larvae >12 mm were distributed still farther west and south than the large larvae. Their distribution extended from western Long Island to North Carolina, with the greatest abundance off Long Island and New Jersey (Fig. 58).

Spawning ended by August. We caught larvae from southern New England to Chesapeake Bay, but in far fewer numbers than in June (Fig. 59). Large larvae dominated the catch, and we caught only one small larva (Table 14). Intermediate-sized larvae were scattered from southern New England to New Jersey. We found large larvae scattered from New England to Chesapeake Bay, and larvae >12 mm mostly off New Jersey.

During the abbreviated cruise in mid-September, we caught only four larvae, the last of the season.

The distribution of all yellowtail flounder larvae was continuous from Cape Cod to Cape Hatteras. The composite figure is strongly influenced by catches in May and June, with the area of greatest abundance extending from Cape Cod to Chesapeake Bay (Fig. 60). We judged, from the distribution of small larvae, that spawning was most concentrated off New Jersey and southern New England. In contrast, larvae >12 mm were concentrated off western Long Island and New Jersey; only four were taken off southern New England. Like most flatfish, yellowtail flounder do not undertake extensive seasonal migrations. Royce et al. (1959) found, however, that adults migrate from waters off western Long Island to southern New England in the spring. Fish tagged off western Long Island in February were caught off southern New England during summer, and back near the release site in winter. Thus, some of the seasonal eastward shift in spawning, implied from the shift in concentrations of our larvae <4 mm, might be attributed to migrating adults. The near-absence of larvae >12 mm off southern New England and their presence off Long Island suggested that larvae originating off southern New England swim or are carried out of the area by currents to the area off New Jersey and Long Island. Royce et al. (1959) also found large numbers of small larvae in samples collected off southern New England in the spring of 1932, but no late-stage larvae either there or to the west. They concluded that the larvae originating off southern New England were carried north or east beyond the area covered by their data. Recently published data on circulation off southern New England, inferred from drift bottle and seabed drifter released between 1960 and 1970, support their conclusion (Bumpus 1973). Furthermore, Sette (1943) presented wind data recorded at Nantucket Shoals Light during June 1932 that could account for the transport of yellowtail flounder larvae to the north or east, as Royce et al. (1959) suggested. Such an occurrence may affect the year class that would normally replenish the yellowtail flounder off Long Island and northern New Jersey.

Royce et al. (1959) surmised from samples collected in 1929 that spawning began in early April at the latest, when bottom temperatures reached 5° to 7°C. Eggs in collections they examined occurred over a minimum bottom temperature of 4.8°C, and recently hatched larvae over bottom temperatures ranging from 4.9°C in early May to 12.3°C in late May. Most of the small specimens in our samples occurred over similar bottom temperatures. We caught 98% of those <4 mm over bottom temperatures between 4.1° and 8.9°C, which is probably commensurate with temperatures where spawning occurred.

Although we caught the most larvae in June, spawning apparently had peaked about the end of April or the beginning of May, as larvae <4 mm were most abundant during the May cruise. No larvae were caught after mid-September (Table 14). Our findings agree closely with those of Royce et al. (1959). They estimated that 90% of the yellowtail flounder landed in New Bedford, Mass., in 1943 spawned between 12 April and 26 June, with heaviest spawning from 4 May to 4 June.

Pseudopleuronectes americanus (Walbaum), winter flounder.—Winter flounder have been captured from as far north as Labrador to as far south as Georgia, but they seldom range north of Newfoundland or south of Chesapeake Bay, where they occur from the inner reaches of the littoral zone to depths of 128 m. Throughout its range, the species is evidently composed of local independent populations, perhaps the most notable being that group of exceptionally large fish found on Georges Bank (Bigelow and Schroeder 1953). Larvae were described by Sullivan (1915), Perlmutter (1939), and Bigelow and Schroeder (1953).

Winter flounder are considered one of our least migratory fish. A separate population seems to inhabit its own river system along the northern half of the Middle Atlantic Bight, where adults move but a few miles offshore to deep cool water during the summer and return to the shallow waters of their respective home bays or rivers for the winter (Perlmutter 1947). Young-of-the-year remain inshore. Spawning occurs in the estuaries during winter and early spring. Eggs are demersal. Although the larvae are pelagic, they become strongly bottom oriented even before completion of metamorphosis, which occurs at about 8 mm (Pearcy 1962).

We caught larvae during the three spring cruises mostly nearshore, but some midway out on the shelf over depths of 55 m. In April, when they were most abundant, their distribution was continuous from Cape Cod to Chesapeake Bay. There were concentrations of larvae off the northern New Jersey coast, and from Delaware Bay southward to Maryland over depths less than 20 m (Fig. 61). Both concentrations were near the mouths of estuaries, and the tide was ebbing when we sampled. Judging from the tidal phase at the time, the known spawning habits of winter flounder, and information from Pearcy (1962), who reported that currents flush 3% of the winter flounder population per day from the upper Mystic River, we assumed that most of the winter flounder larvae collected during the three spring cruises originated in estuaries and were subsequently carried seaward by currents. Using incubation times and growth rates reported by Bigelow and Schroeder (1953), we calculated that most of those caught in April had been spawned during the latter half of March (Table 15).

In May, the distribution of larvae was again continuous from Cape Cod to Chesapeake Bay, but the center of abundance occurred off southern New England, or farther north than in April (Fig. 62). Larvae occurred only off Cape Cod in June (Fig. 63). We assumed from their absence farther south that spawning had ended in the adjacent estuaries.

The characteristic south-to-north progression in spawning that we found prevalent in offshore spring spawners is apparent in our collections of winter flounder larvae. Since winter flounder populations in the bight are isolated when spawning, each having its own home river system, the northward progression of spawning that is evident in our

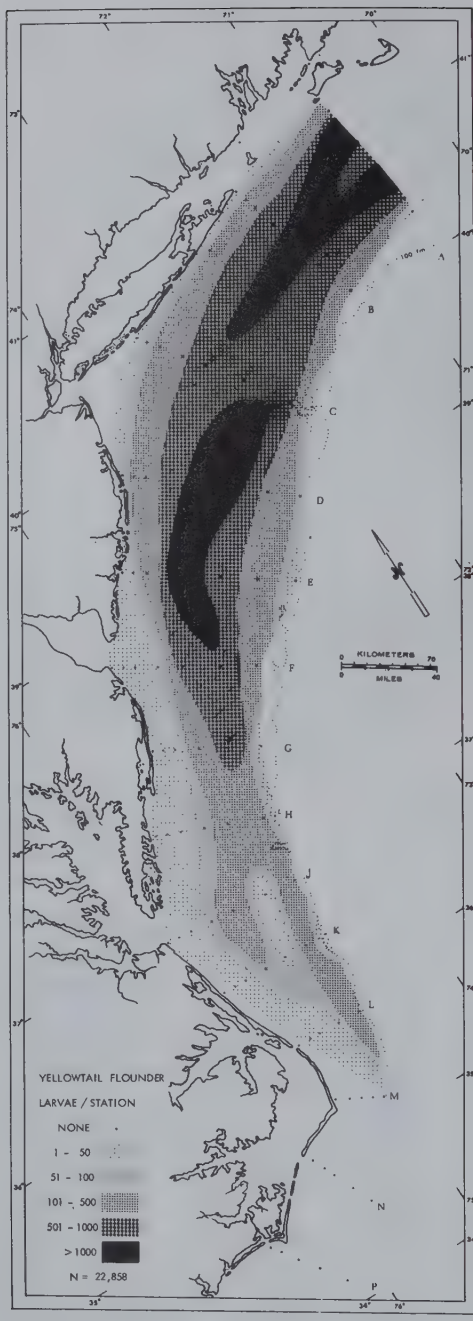


Figure 60.—Distribution and relative abundance of yellowtai flounder, *Limanda ferruginea*, larvae collected during 1965-6 survey.

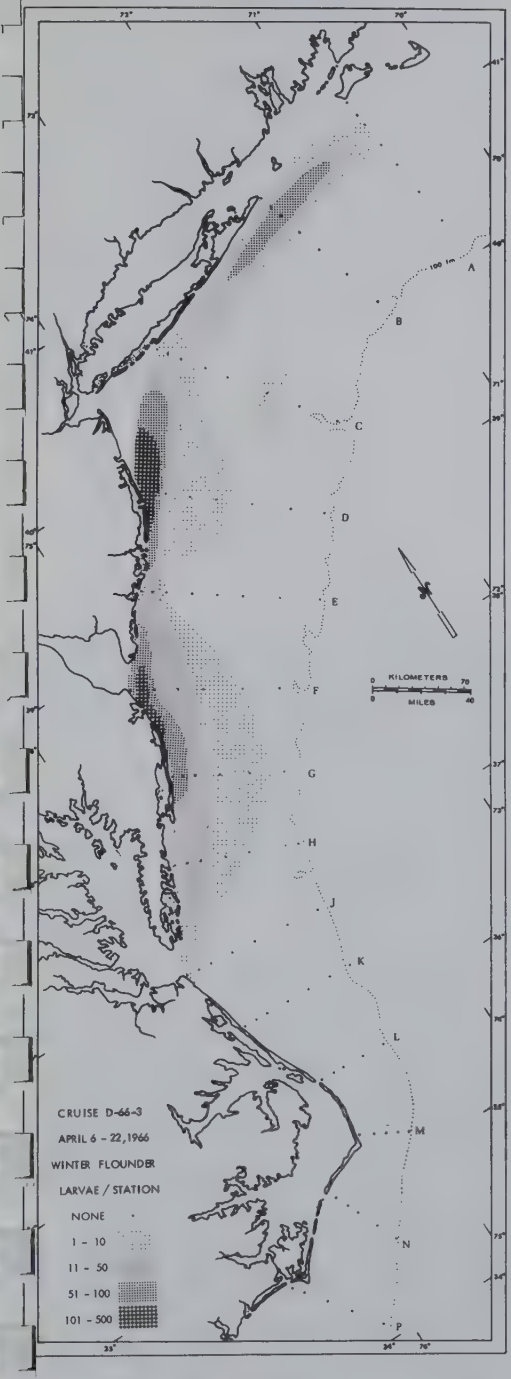


Figure 61.—April 1966. Distribution and relative abundance of winter flounder, *Pseudopleuronectes americanus*, larvae.

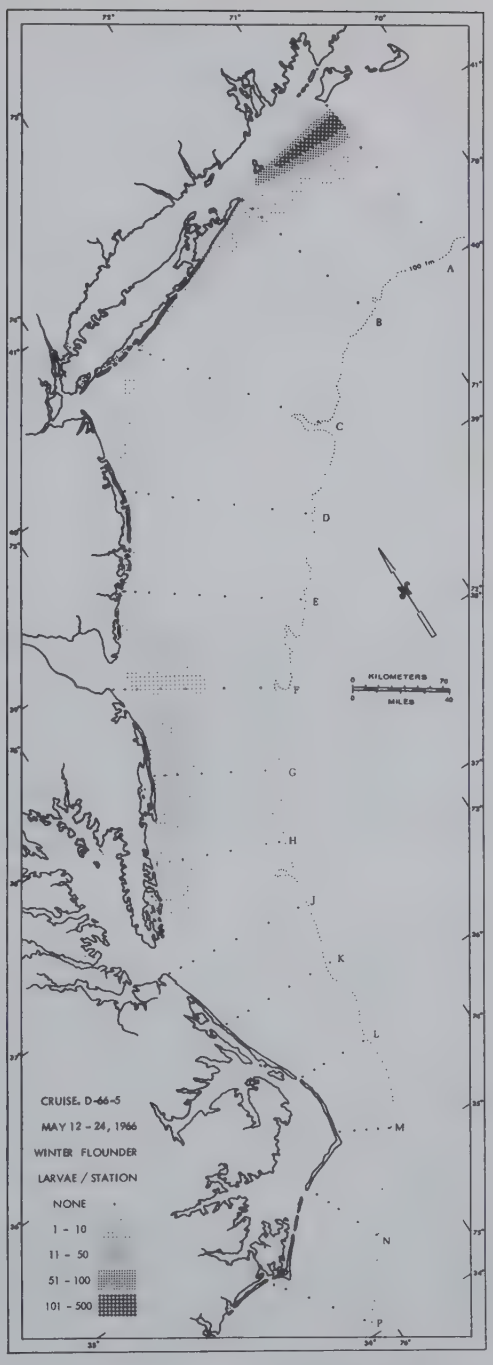


Figure 62.—May 1966. Distribution and relative abundance of winter flounder, *Pseudopleuronectes americanus*, larvae.

Table 15.--The seasonal distribution of winter flounder, Pseudopleuronectes americanus, larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date 66-3 Apr.	66-5 May	66-7 June	Total
	Number of larvae			
2.1- 3.0	15	2		17
3.1- 4.0	612	261	53	926
4.1- 5.0	313	149	120	582
5.1- 6.0	70	24	113	207
6.1- 7.0	22	70	19	111
7.1- 8.0		39	2	41
8.1- 9.0	1	22		23
9.1-10.0		3		3
Total	1,033	570	307	1,910

data strongly suggests that warming spring temperatures are a triggering mechanism for the onset of spawning. Most of the larvae caught during the three spring cruises occurred within 25 km of shore (Fig. 64). Whether or not they were flushed from nearby estuaries or spawned at sea, chances for their survival seem remote, since estuaries are apparently necessary as both spawning and nursery grounds. Our trawl records from coastal groundfish surveys support this theory. Young-of-the-year have not been collected along the oceanfront, but they are caught in the estuaries.

III. Family Soleidae—Soles

Gymnachirus melas Nichols, naked sole.—Naked sole range from Massachusetts to Florida and into the Gulf of Mexico, but only one specimen has been collected north of Cape Hatteras. They are the only member of the family found in offshore shelf waters off the eastern United States (Dawson 1964). From gonadal studies, Topp and Hoff (1972) estimated that spawning occurred from May to November off the west coast of Florida. Larvae have not been described. Larval identifications are based on morphological characters, fin ray counts, pigmentation, and the reported range of adults.

We caught 12 specimens between 3.2 and 8.2 mm. All were caught between capes Hatteras and Lookout from April through August, half of them in May. Since we caught all the larvae except one on the outer half of the shelf, they had probably been transported into our survey area by the Gulf Stream.

IV. Family Cynoglossidae

Symphurus spp., tonguefishes.—The ranges of five species of *Symphurus* extend into the survey area. None of the five are common north of Cape Hatteras, but some occur more regularly than others. *Symphurus diomedianus* (Goode and Bean) range from North Carolina to Brazil; *S. minor* Ginsburg from Nova Scotia to Florida and into the Gulf of Mexico; *S. plagiusa* (Linnaeus) from New York t Bahamas and Greater Antilles, and into the Gulf of M *Symphurus civitatus* Ginsburg has been collected North Carolina to Florida and the Gulf of Mexico, a *pusillus* (Goode and Bean) from New York and the G Mexico (Ginsburg 1951; Topp and Hoff 1972). Hilde and Cable (1930) described early development of a to fish they thought was *S. plagiusa*. Larvae of the species have not been described.

Our collections may contain larvae of all five specie perhaps representatives of one or more species that a found as adults in the survey area. We could identify specimens of only one, *S. minor*. Because me characters of the others widely overlap, we could not positive identifications beyond the generic level, so larvae are treated as *Symphurus* spp.

The presence of more than one species of *Symp* larvae in our collections, coupled with the unpredi influence of the Gulf Stream on their distribution, interpretation of the data speculative. Although we larvae the year-round, differences in seasonal distribut well as size and numbers of larvae make it doubtful tha one species dominated the catch on all cruises. interpreted the catch as being represented by at lea species that have overlapping spawning seasons together continued the year-round.

Because *S. plagiusa* is a shoal-water species limi depths <26 m as adults (Ginsburg 1951), we conclude most of the larvae caught from January to May at d >40 m represented one or more of the other species. on their size and the pattern of distribution, larvae from January to April were spawned south of Cape L and subsequently transported into the survey area b Gulf Stream (Fig. 65). Some of those caught in May also have been spawned south of our survey area, b concentration of small larvae nearshore between Lookout and Hatteras might have been spawned l (Fig. 66).

The catch declined in June. The distribution of resembled that of the previous two cruises, and pr

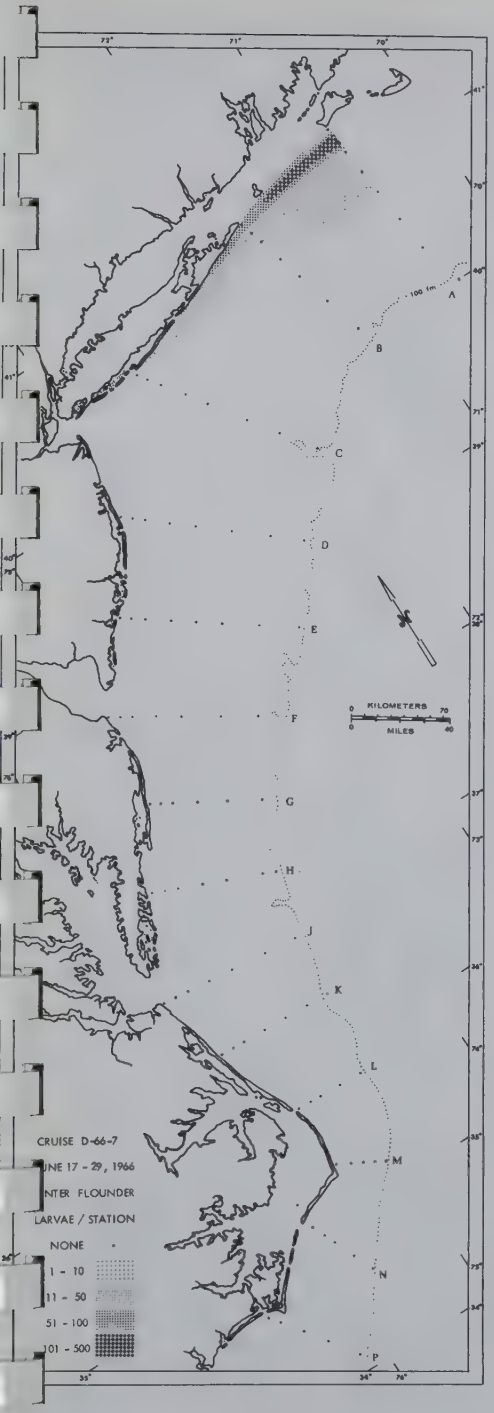


Figure 63.—June 1966. Distribution and relative abundance of winter flounder, *Pseudopleuronectes americanus*, larvae.

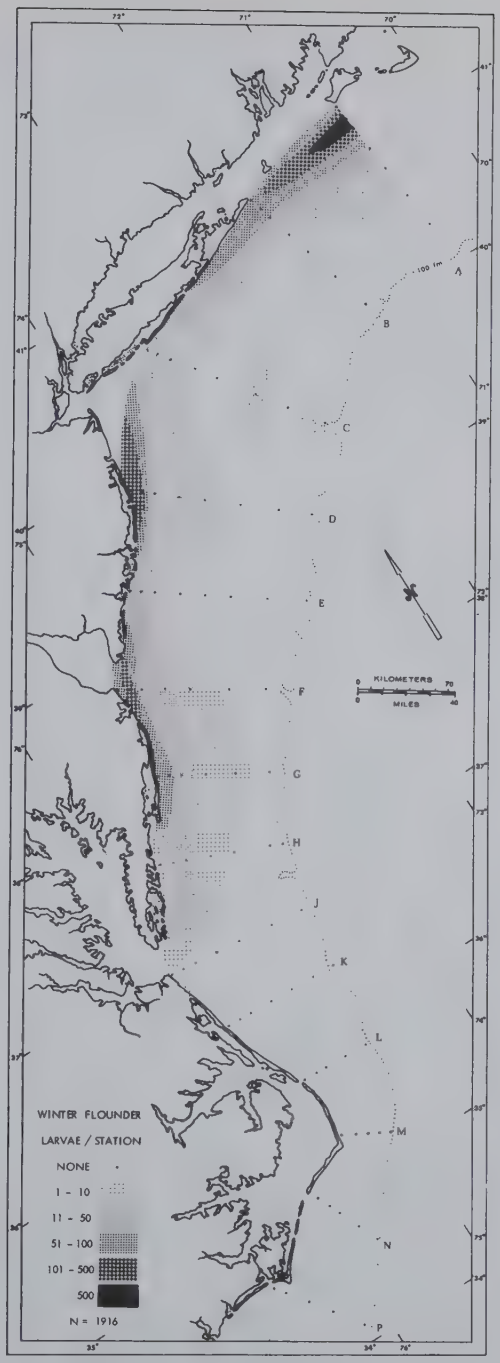


Figure 64.—Distribution and relative abundance of winter flounder, *Pseudopleuronectes americanus*, collected during 1965-66 survey.

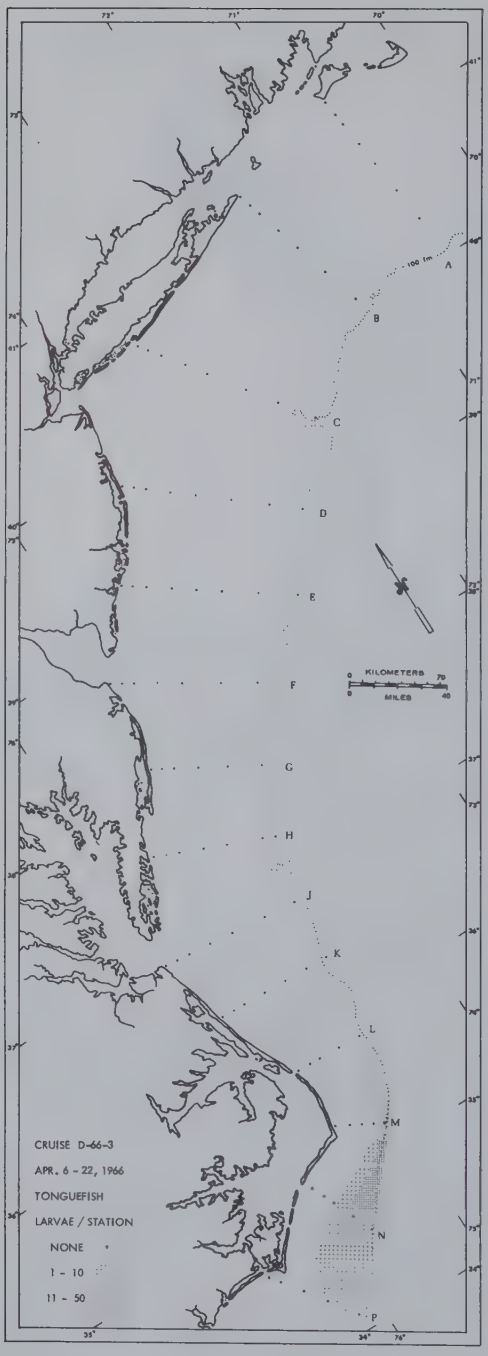


Figure 65.—April 1966. Distribution and relative abundance of *Symphurus* spp. larvae.

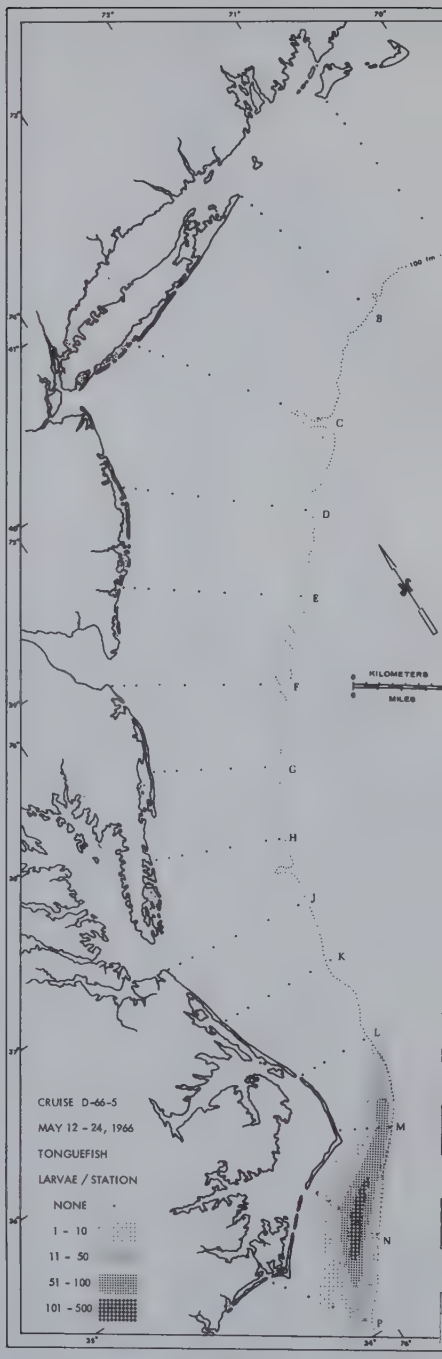
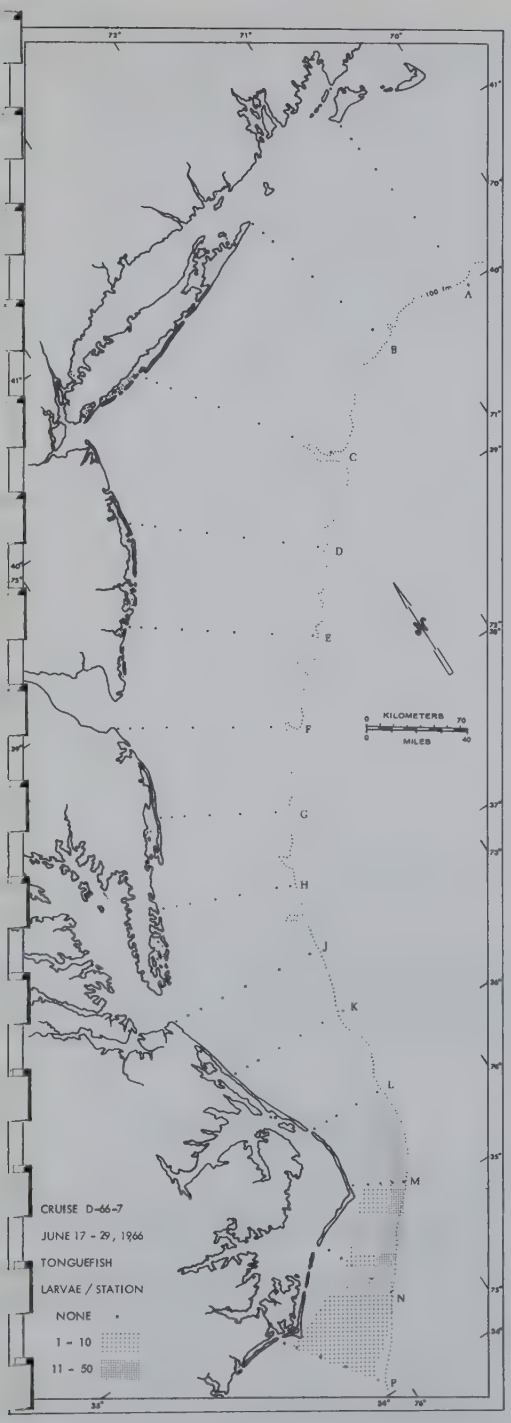


Figure 66.—May 1966. Distribution and relative abunda
Symphurus spp. larvae.



ure 67.—June 1966. Distribution and relative abundance of *Symphurus* spp. larvae.

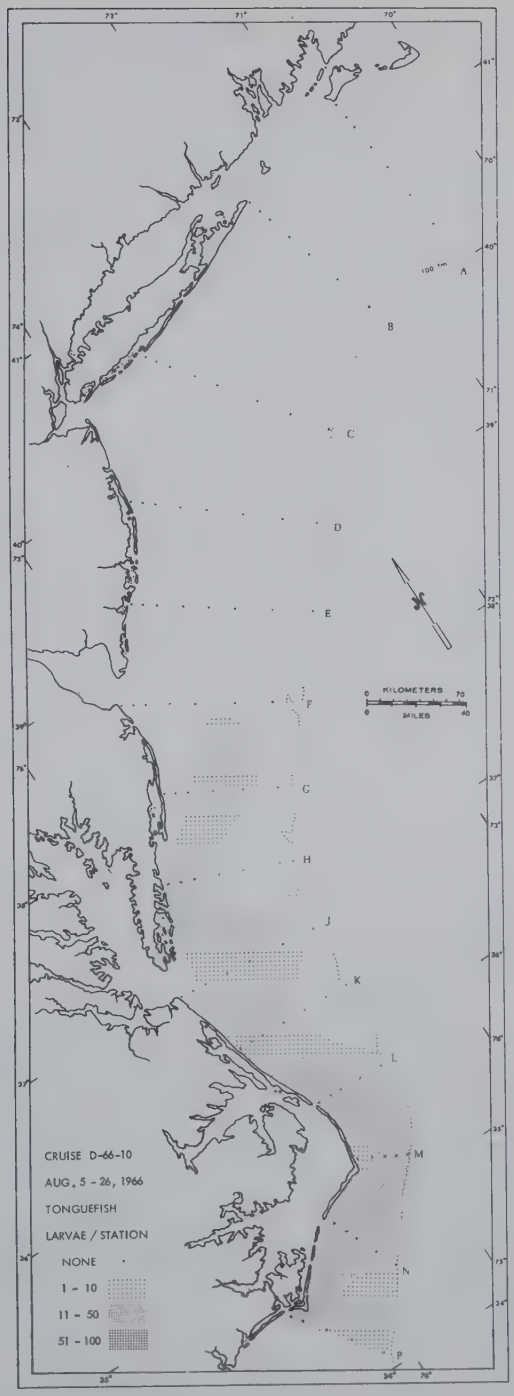


Figure 68.—August 1966. Distribution and relative abundance of *Symphurus* spp. larvae.

Table 16.--The seasonal distribution of Symphurus spp. larvae by size.

Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date								
	66-1 Jan.-Feb.	66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	Total
	Number of larvae								
2.1- 3.0				5	33	2	4		44
3.1- 4.0			49	19	74	17	29	4	192
4.1- 5.0		3	67	9	49	21	20	7	176
5.1- 6.0	1	5	53	8	39	7	10	4	127
6.1- 7.0	5	2	28	4	16	11	7	2	75
7.1- 8.0	1	3	24	4	7	12	3	2	56
8.1- 9.0			7	1	10	9	2	2	31
9.1-10.0		2	9	3	4	5	3	3	29
10.1-11.0		3	10	2	5	2	2	1	25
11.1-12.0		3	5		2	5		1	16
12.1-13.0		2	1		1	4		2	10
13.1-14.0		1	3			4	3	1	12
14.1-15.0			2		1		2		5
15.1-16.0			1				1		2
16.1-17.0						1			1
17.1-18.0		1							1
Total	7	25	259	55	241	100	86	29	802

consisted largely of the same species that we caught earlier (Fig. 67).

The distribution of larvae changed in August. Most specimens occurred at inshore stations, and the areal extent of their distribution reached northward to Maryland (Fig. 68). These shifts in distribution and the increased catch over June (Table 16) led us to conclude that the catch consisted largely of a different species, probably *S. plagiusa*, the most commonly occurring tonguefish off North Carolina.

By October, the catch began to decline again (Table 16). Larvae were scattered, and their distribution had receded to waters south of Chesapeake Bay (Fig. 69). The catch declined further in November, and the distribution of larvae continued to recede southward. Catches were light, and most larvae occurred along the outer half of the shelf south of Cape Hatteras, an area traversed by the Gulf Stream (Fig. 70). In December (1965), we caught *Symphurus* specimens only south of Cape Hatteras (Fig. 71). Catches on the three fall cruises presumably represented a late spawning of *S. plagiusa*, and an influx of one or more of the other four species from south of Cape Lookout.

Hildebrand and Cable (1930) concluded from their larval collections that *S. plagiusa* spawned from May to October near Cape Lookout, with a peak in June. They apparently discounted the possibility of their specimens being anything but *S. plagiusa*, and may have been justified in doing so since they sampled to a maximum depth of about 21 m. Throughout the year, we caught *Symphurus* larvae from Maryland to North Carolina. Their center of abundance occurre seaward stations over depths of 50 to 185 m betwee North Carolina capes, and, with the exception of catche August to early October, their overall distribution survey area appeared strongly influenced by the Gulf St (Fig. 72).

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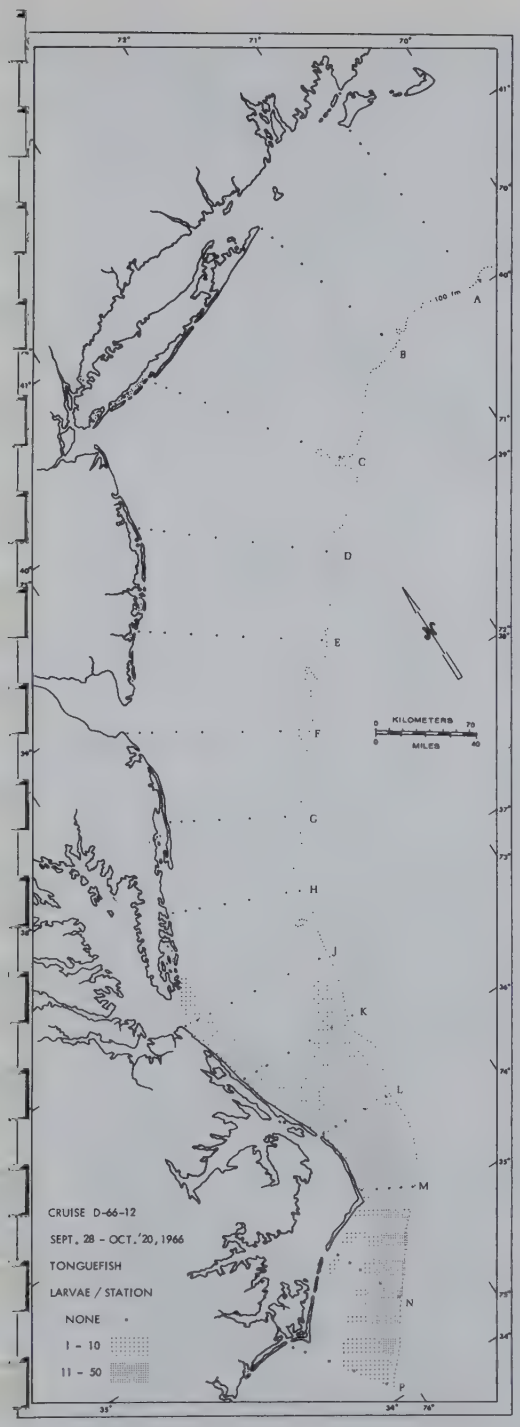


gure 69.—September to October 1966. Distribution and relative abundance of *Symphurus* spp. larvae.

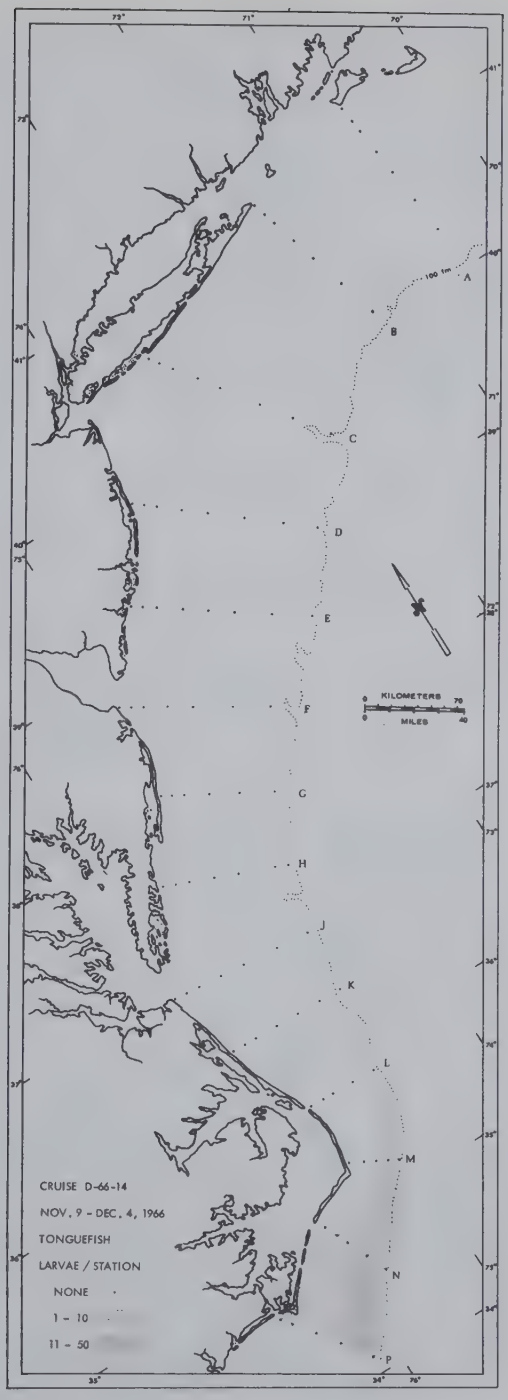


Figure 70.—November to December 1966. Distribution and relative abundance of *Symphurus* spp. larvae.

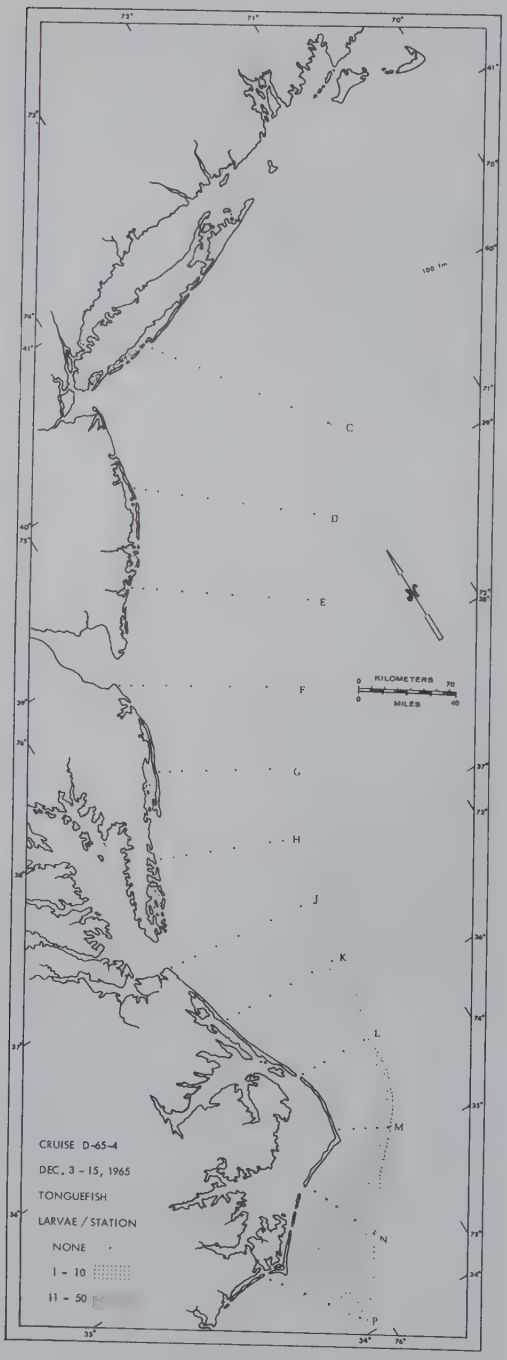
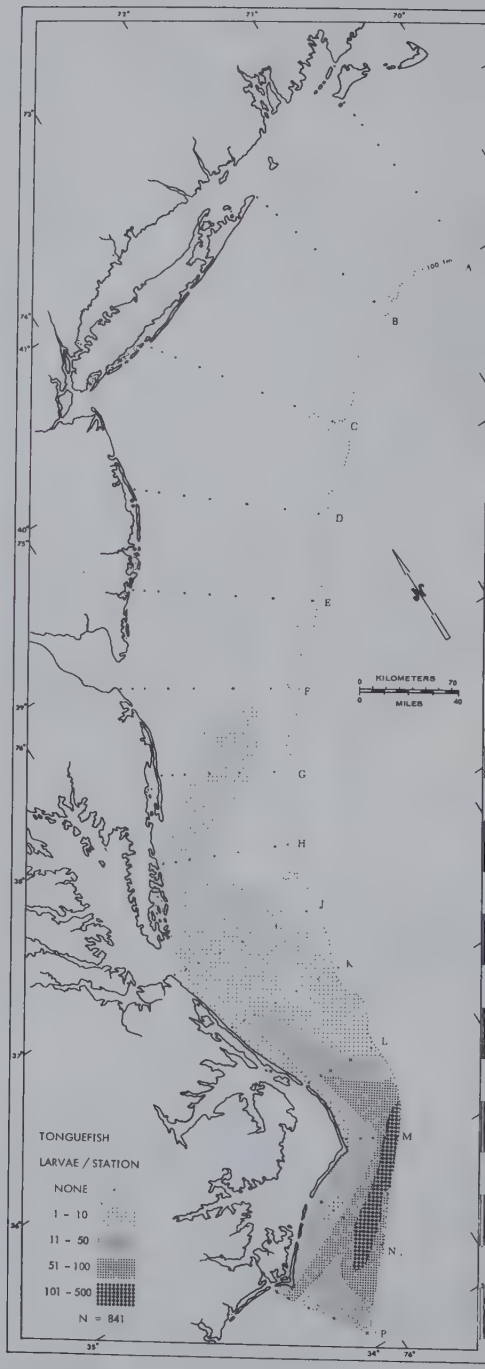


Figure 71.—December 1965. Distribution and relative abundance of *Symphurus* spp. larvae.



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